CANDIDATE SUBSTANCES LIST FOR BANS OR PHASE-OUTS

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Candidate Substances List for Bans or Phase-Outs

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Executive Summary

In June 1991 the Ontario Ministry of the Environment's Hazardous Contaminants Branch and Water Resources Branch were directed to establish a list of candidate substances to be considered for banning, phasing out or use/release reductions. The results were: (i) a process for selecting the substances, (ii) primary and secondary lists of substances for consideration, (iii) a review of the data on loadings of the primary list substances to receiving waters from industrial and municipal direct point source dischargers, (iv) a hazard evaluation of industrial and municipal effluents monitored under MISA* and (v) a review of the receiving water impacts, including sediment and biota impacts, attributable to point and non-point source inputs of substances on the Primary List.

The Primary List of Candidate Substances for Bans or Phase-Outs is a list of substances present in or discharged to Ontario surface waters which, out of the approximately 800 substances assessed, *are most inherently hazardous due to their persistence in water or sediment, potential to bioaccumulate and toxicity.* It is recommended that these substances be given first priority in considering candidate substances for banning, phasing out, or use/release reduction.

The Primary List is composed of the following 21 substances or substance groups:

anthracene
arsenic
benzo[*a*]pyrene
benzo[*ghi*]perylene
benz[*a*]anthracene
DDT (+ DDD & DDE)
1,4-dichlorobenzene
3,3'-dichlorobenzidine
dieldrin
hexachlorobenzene
alpha-hexachlorocyclohexane (α-HCH)
gamma-hexachlorocyclohexane (γ-HCH)
mercury
mirex
pentachlorophenol
perylene
phenanthrene
polychlorinated biphenyls (PCBs)
polychlorinated dibenzo-p-dioxins and -furans (PCDD/Fs)
toxaphene
tributyl tin

* Municipal-Industrial Strategy for Abatement, a program under which effluent from industrial and municipal sources directly discharged to surface water are monitored and regulated.

Although all Primary List substances except 3,3'-dichlorobenzidine have been detected at elevated concentrations in the Great Lakes basin, it has been demonstrated that 17 of the substances have caused impairments of water, sediment or biota in Ontario based on exceedences of available criteria. Of the remaining four substances, 1,4-dichlorobenzene and toxaphene have not been detected at levels which exceed established criteria, and 3,3'-dichlorobenzidine and tributyl tin could not be evaluated from a water/sediment/biota impairment perspective because no appropriate criteria have been established for these substances.

Nineteen of the Primary List substances have been monitored for under Ontario's MISA program or in the Municipal Water Pollution Control Plants Study*. It has been demonstrated that of these 19 substances, 15 are being directly discharged to surface waters by Ontario-based industrial point sources or municipal water pollution control plants. Several substances are being discharged at high concentrations considered to be acutely toxic to aquatic biota, including arsenic, mercury, PCBs, PCDDs and benzo[*a*]pyrene.

A Secondary List composed of 46 substances is recommended as a "second tier" set of substances, to be considered after those on the Primary List have been addressed. The Secondary List of candidate substances are toxic and either persistent or bioaccumulative, or are both persistent and bioaccumulative but somewhat less toxic than those on the Primary List. These substances have not been evaluated in terms of loadings or environmental impacts.

The pesticides evaluated are those identified on the IJC Water Quality Board's list of critical water pollutants or are produced as byproducts of industrial processes. Other pesticides which may be present in effluent from municipal water pollution control plants will be considered in a later stage of this initiative.

This effort represents a major step towards creating a comprehensive multimedia bans or phase-outs list, a list of substances of concern from the perspectives of air, water, sediment, soil, waste and biota. These substances will be targeted for phase-outs, bans or use/release reduction. Work is currently underway to address substances released primarily to air and land that were not identified in this stage.

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* A 1987 survey of 37 Ontario municipal water pollution control plants.

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Part I

Development of a Candidate Substances List for Bans or Phase-Outs

1 Objective

The Environmental Program Principles Review Project (EPPRP) was initiated in March 1991 for the purpose of establishing an integrated approach for the development and delivery of the Ontario Ministry of the Environment's programs. One subsidiary project under the EPPRP was the establishment of a list of persistent, bioaccumulative, toxic substances for multimedia release reduction, banning and/or phase-out ("sunsetting").

As a way of developing a method for selecting candidate substances, and as the first step towards creating a comprehensive multimedia bans or phase-outs list, an initial list was to be established composed of highly hazardous substances present in or discharged to Ontario's surface waters.

The objective of creating a list of candidate substances for bans or phase-outs was to identify those substances released into or present in Ontario's surface waters which pose the greatest hazard, based on their potential to cause adverse impact on the environment. Three general characteristics of substances influence the severity and duration of such adverse impacts - persistence, bioaccumulation potential and toxicity, therefore the first step in the process is to identify those toxic contaminants that are persistent in water or sediment and are bioaccumulative. Such substances are considered to be candidates for banning or phasing out.

The list of candidate substances, therefore, is a list of substances which due to their physicochemical and toxicological properties are most inherently hazardous and should ideally not be permitted to enter the environment. However, of all the substances in the environment, those selected as first priority for consideration for bans or phase-outs are not necessarily those that present the greatest environmental health *risk* . "Risk" is a function of both exposure level and degree of adverse effect. The limited amount of exposure information available precluded the development of a systematic approach for identifying substances that pose the greatest risk. Risk assessment may be considered at a later stage after detailed exposure-related information has been obtained, *e.g.* environmental concentrations, contaminant loadings from point, diffuse and transboundary discharge sources and further evidence of demonstrable effects on biota at contaminated sites.

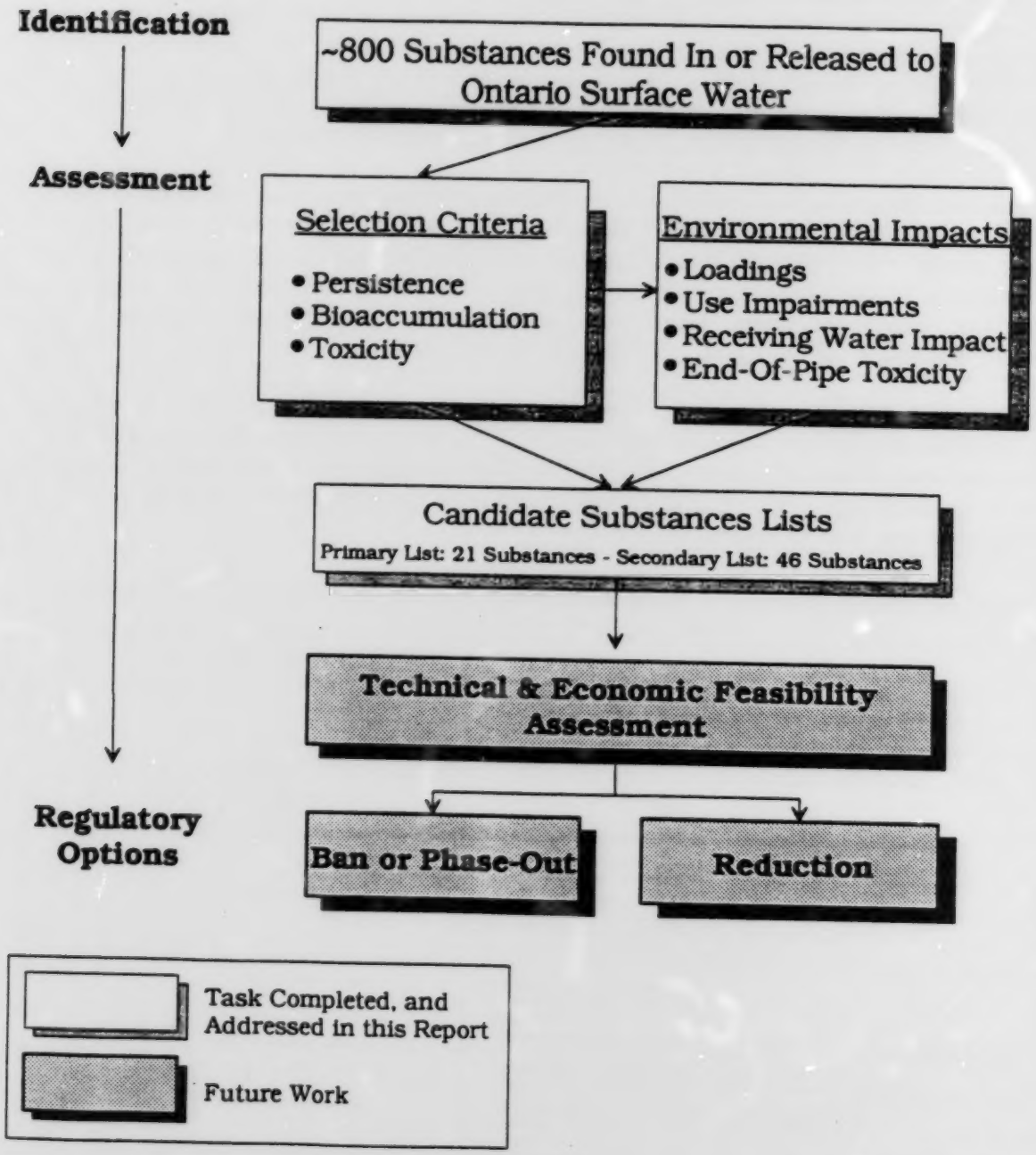
If a substance is regulated to a degree such that none of it enters the environment, the goal of *zero discharge* of that substance has been achieved. In its July 1991 Virtual Elimination Task Force interim report, the International Joint Commission defined zero discharge as the elimination of all inputs to the Great Lakes basin ecosystem of persistent toxic substances produced, used, distributed or disposed of in or around the basin, whether from direct release into waterways or the atmosphere, indirect releases such as agricultural and urban runoff, or inadvertent releases such as from spills. To obtain zero discharge, all sources of the target substances must be eliminated, rendering those substances unavailable and thus preventing any

opportunity for their entry to the environment. Regulatory instruments employed to attain zero discharge of a substance may be in the form of a ban on the use and generation of the substance or a phasing out of the use and generation of the substance (*i.e.* incremental reductions leading ultimately to a complete ban). Where a ban or phase-out is not technically or socioeconomically feasible, reduction in use of the substance or reduction in the release of the substance to the environment are alternate regulatory options.

The overall process by which substances are selected for as candidates for bans or phase-outs, further assessed and then regulated using various options is illustrated in Figure 1.1. Future efforts will involve assessment of exposure potential, the technical and economic feasibility of bans or phase-outs and the determination of which regulatory options are appropriate.

Figure 1.1

Selection of Candidate Substances for Bans or Phase-Outs and Further Actions



2 Previous Bans and Phase-Outs

In Canada, the following industrial chemicals have been banned or are being phased out:

PCBs (polychlorinated biphenyls)
PBBs (polybrominated biphenyls)
PCTs (polychlorinated terphenyls)
Mirex
CFCs (chlorofluorocarbons).

Various courses of action can be taken in the case of pesticides. The registration of the pesticide can be cancelled or its uses suspended. They can be phased out by allowing use of existing stocks only, or a manufacturer may decide to withdraw its product from the market before regulatory action is taken to restrict it.

A few examples are given in Table 1.1 to illustrate the concerns that led to the control of particular substances and factors involved in the decision. The concerns listed are those considered during the regulatory review and do not necessarily represent all of the adverse effects of the compounds, nor does it include information found after regulatory action was taken. Since the experience in the United States is similar to that in Canada, only the Canadian situation is presented.

In all cases, the persistence of the chemical resulted in environmental levels that were detrimental or considered potentially harmful. The availability of substitutes and the economic cost of adjustment to a different technology influenced the choice of a rapid ban or gradual phase-out. The costs associated with the bans have always been considered less than the potential benefits.

Table 1.1: Previous Bans and Phase-Outs

Mirex	**Uses**	- In Canada, used as a fire retardant only.
	Regulatory history	1978 All uses prohibited
	Environmental concerns	- Persistent in the environment - Widely dispersed from source of emission - Contamination of fish and fish eating birds - Degradation product also persistent and toxic
	Health concerns	- Caused tumours in experimental animals - Mirex contained a carcinogenic impurity
	Socio-economic factors	- Not imported into Canada since 1969 - Alternative chemicals in regular use - No use for which Mirex is indispensable
PCBs	**Uses**	- Hydraulic fluids, heat-exchange and dielectric fluids, plasticizers, in pesticides, caulking compounds, adhesive paints, printing ink, carbonless copy paper. Present uses is limited to existing transformers.
	Regulatory history	1977 Most non-electrical uses prohibited Manufacture banned in North America 1980 Restricted to existing equipment already in use Import of PCB filled equipment prohibited PCBs cannot be used to fill existing equipment (Oils with less than 50ppm PCBs are not considered PCBs) 1982 Ontario regulates the transport and storage of PCB waste 1985 Sale of PCB equipment prohibited Quantities of PCBs that can be released is restricted
	Environmental concerns	- Persistent - Widely dispersed far from source of release - Bioaccumulative - Adverse reproductive effects in fish, fish eating birds and mink documented at exposure to environmental levels
	Health concerns	- Accidental food poisoning resulted in severe effects in Japan - Caused cancer in experimental animals - PCBs could be contaminated with polychlorinated dibenzofurans - Fish caught in Lake Ontario and in the St. Lawrence River often contaminated at levels above Canadian guidelines
	Socio-economic factors	- In 1972, Monsanto, the sole producer of PCBs in North America, voluntary restricts sale for enclosed electrical uses only; voluntarily stopped production in 1977 - Alternative heat transfer and hydraulic fluids readily available - Immediate removal of all PCB containing equipment would severely disrupt electricity distribution - Potential adverse effect on the Great Lakes fisheries if unrestricted use continued
Alachlor	**Uses**	- To control weeds in a variety of crops
	Regulatory history	1985 Use restricted 1986 No longer registered
	Environmental concerns	- Use of Alachlor according to label instructions results in ground and surface water contamination
	Health concerns	- An animal carcinogen
	Socio-economic factors	- Alternatives are readily available - To minimize disruption, use of available stocks of Alachlor was allowed during 1985
DDT	**Uses**	- To control a wide variety of insects and other pests
	Regulatory history	1969 Ontario restricts to 3 specialized uses 1972-3 Ontario restricts to control of bats 1974 Ontario allows DDT to control mice as well as bats 1988 All uses disallowed in Ontario
	Environmental concerns	- Persistent in the environment - Widely dispersed from source of emission - Bioaccumulative - Adverse effects on fish-eating birds and predatory fish
	Health concerns	- No human health concerns
	Socio-economic factors	- Due to pest resistance, other pesticides were regularly being used - More effective and less persistent alternatives available for most uses although sometimes at increased cost

3 Other Agencies' Approaches to Substance Designation

3.1 U.S. EPA Pollution Prevention Act "50% Reduction" Chemicals

As an initiative under the Pollution Prevention Act, the U.S. EPA identified 17 chemicals for voluntary 50% emission reduction by 1995 (Table 1.2). The following criteria were used to choose the chemicals:

- The top 100 production chemicals on the Toxic Release Inventory
- High percentage release when compared to production volumes
- Technically and economically feasible
- Chemicals subject to the Clean Air Act
- Exposure levels indicate a potential risk to health or the environment
- Significant releases are occurring
- Multiple exposure and cross-media contamination potential are high or hot-spots are known to exist
- Current treatment and disposal methods are not completely satisfactory

3.2 U.S. EPA Clean Air Act "90% Reduction" Chemicals

Under the Clean Air Act, the U.S. EPA has identified 35 high risk air pollutants for which 90% emission reduction will have to be achieved by January 1st, 1994 (Table 1.3). The procedure used to select those chemicals is as follows:

Tier 1: For the 189 substances on the Clean Air Act Toxic Release Inventory, toxicity data (human toxicity only) was collected (carcinogenicity, reproductive toxicity, acute toxicity and "other" toxicity);

Tier 2: A model was used to predict the maximum dose an individual would receive at a distance of 500m from the source, assuming an emission rate of 10 tonnes per year. Two benchmark doses were then set, *i.e.* 10^{-5} lifetime cancer risk, and 10 x reference dose for other effects;

Tier 3: If one or more sources would lead to exceedence of the benchmark doses above, the substance was listed. Also, the IARC Group A (confirmed human carcinogen) substances benzene, benzidine, chloromethyl methyl ether and bis(chloromethyl)ether were added to the list.

3.3 U.S. EPA "Chemicals of Highest Concern" List

The March 1991 U.S. EPA draft document *Assessment and Control of Bioconcentratable Contaminants in Surface Waters* contains a list of 33 "chemicals of highest concern" (Table 1.4 - 17 pesticides, 7 PCB mixtures and 9 other organics) which pose serious risks to human health due to their high toxicity and high bioconcentration potential. These substances bioconcentrate in fish and shellfish to levels hazardous to human health, even when present in ambient water at very low concentrations. However,

for this list the EPA did not use any specific criteria for defining "high bioaccumulation" or "high toxicity".

3.4 IJC Water Quality Board List of Critical Water Pollutants

The International Joint Commission (IJC)'s Water Quality Board has listed 11 critical water pollutants including PCBs, 2,3,7,8-TCDD and benzo[*a*]pyrene and the pesticides DDT, dieldrin, mirex and toxaphene (Table 1.5). The Board's "best professional judgement" selections were based on toxicity, bioconcentration and persistence, however specific criteria are not available. Note that of the pesticides on the IJC's list, all but dieldrin have effectively been banned in Ontario. Dieldrin has minor use, restricted to termite control.

Table 1.2: U.S. EPA Pollution Prevention Act
Targeted Chemicals for Voluntary 50% Reduction by 1995*

benzene
cadmium & compounds
carbon tetrachloride
chloroform
chromium & compounds
cyanides
dichloromethane
lead & compounds
mercury & compounds
methyl ethyl ketone
methyl isobutyl ketone
nickel & compounds
tetrachloroethylene
toluene
trichloroethane
trichloroethylene
xylenes

* - 2,3,7,8-TCDD is also included, although not on the basis of production volume, etc.

Table 1.3: U.S. EPA Clean Air Act
High Risk Pollutants for 90% Reduction

I. Carcinogens
acrylamide
acrylonitrile
arsenic compounds (inorganic, including arsine)
asbestos
benzene
benzidine
benzotrichloride
beryllium compounds
bis(chloromethyl)ether
1,3-butadiene
cadmium compounds
chlordane
chloromethyl methyl ether
chromium compounds
coke oven emissions
dichloroethyl ether (= bis(2-chloroethyl)ether)
ethylene dibromide (= dibromoethane)
ethylene oxide
heptachlor
hexachlorobenzene
hydrazine
1,2-propylenimine (= 2-methyl aziridine)
2,3,7,8-TCDD
1,1,2,2-tetrachloroethane
vinyl chloride
vinylidine chloride (= 1,1-dichloroethylene)

II. Noncarcinogens
acrolein
acrylic acid
chloroprene
dibenzofurans
mercury compounds
methyl isocyanate
methylene diphenyl diisocyanate
phosgene
2,4-toluene diisocyanate

Table 1.4: U.S. EPA March 1991 Draft Document
Assessment and Control of Bioconcentratable Contaminants in Surface Waters
Chemicals of Highest Concern

aldrin
bis(2-ethylhexyl)phthalate
chlordane
danitol
3,3'-dichlorobenzidine
dicofol
dieldrin
ethyl-p-nitrophenylphenylphosphorothioate (EPN)
heptachlor
heptachlor epoxide
hexachlorobenzene
gamma-hexachlorocyclohexane
alpha-hexachlorocyclohexane
beta-hexachlorocyclohexane
technical-grade hexachlorocyclohexane
hexachlorophene
4,4'-methylene bis(N,N'-dimethyl)aniline
mirex
N-nitroso-di-n-butylamine
pentachlorobenzene
p,p'-DDD
p,p'-DDE
p,p'-DDT
PCB - aroclor 1016
PCB - aroclor 1221
PCB - aroclor 1232
PCB - aroclor 1242
PCB - aroclor 1248
PCB - aroclor 1254
PCB - aroclor 1260
1,2,4,5-tetrachlorobenzene
2,3,7,8-TCDD
toxaphene

Table 1.5: International Joint Commission Water Quality Board
Critical Pollutants List

alkylated lead
benzo(a)pyrene
DDT and metabolites (DDE & DDD)
dieldrin
hexachlorobenzene
mercury
mirex
PCBs
2,3,7,8-TCDD
2,3,7,8-TCDF
toxaphene

4 Substances Considered

The set of approximately 800 substances considered in this exercise were derived from those known as the "MISA Primary Group" of substances ("MISA", the Municipal-Industrial Strategy for Abatement, is a monitoring and control program that was initiated by the Ontario Ministry of the Environment in 1986 with the objective of reducing water pollution originating from industrial and municipal dischargers). These are substances identified as being present in Ontario surface water by the International Joint Commission (IJC), the Niagara River Toxics Committee, and through various MOE ambient surface water surveys, as well as substances detected in discharges to Ontario surface water from industrial point sources and municipal sewage treatment plants.

Pesticides that are not on the IJC Water Quality Board's critical pollutants list and are not produced as byproducts of industrial processes were not considered because at present this initiative's primary focus is on industrial point source direct discharges. Such sources are minor contributors to pesticide releases into the environment. Pesticides are also being dealt with under separate, specific programs and legislation. Note also that of the pesticides on the IJC Water Quality Board's critical pollutants list all but dieldrin have already been phased out in Ontario.

5 Criteria for Listing Substances on the Primary List of Candidate Substances for Bans or Phase-Outs

5.1 Determination of Specific Criteria

As mentioned in Section 1 above, the first step in selecting candidate substances for bans or phase-outs was to identify toxic contaminants that are persistent in water or sediment and are bioaccumulative. To do so, specific definitions of "persistent", "bioaccumulative" and "toxic" were required.

The rationale for banning particular substances in the past were examined. Unfortunately, specific criteria for banning substances released to water do not appear to exist.

Listing criteria had been developed previously for the purpose of placing substances on MISA's Effluent Monitoring Priority Pollutants List (EMPPL). Substances had been evaluated according to a scoring system that considered persistence, bioaccumulation and a number of toxic effects. The scoring system is fully documented in the publication *The Ontario Ministry of the Environment Scoring System* (Ontario Ministry of the Environment, Hazardous Contaminants Branch, 1990); a summary table is provided as Table 1.6.

For a given property, substances receiving a score higher than a defined cutoff value were placed on the EMPPL. These cutoff values were arrived at using the best professional judgement of a number of Ministry staff from different branches and with various backgrounds. However, the purpose of the EMPPL was to support a

Table 1.6: Ontario MOE Scoring System Summary Chart

Parameter Name	Endpoint & Units	Scoring Criteria 0	4	7	10
Environmental Persistence	$t_{1/2}$ (days)	≤10	<10 to 50	<50 to 100	>100
Bio-accumulation	BCF Log k_{ow}	≤20 ≤2.0	>20 to 500 >2.0 to 4.0	>500 to 15000 >4.0 to 6.0	>15000 >4.0

Parameter Name	Endpoint & Units	0	2	4	6	8	10
Acute Lethality	oral LD_{50} mg/kg	>5000	>500-5000	>50-500	>5-50	>0.5-5	≤0.5
	dermal LD_{50} mg/kg	>5000	>500-5000	>50-500	>5-50	>0.5-5	≤0.5
	inhal. LD_{50} mg/m³	>15000	>1500-15000	>150-1500	>15-150	>1.5-15	≤1.5
	aquatic LC_{50} mg/L	>1000	>100-1000	>10-100	>1-10	>0.1-1	≤0.1
Sublethal Effects, Non-Mammals	aquatic EC_{50}, mg/L MATC, mg/L NOAEC, mg/L	≥20 ≥2 ≥0.2	2-<20 0.2-<2 0.02-<0.2	0.2-<2 0.02-<0.2 0.002-<0.02	0.02-<0.2 0.002-<0.02 0.0002-<0.002	<0.02* <0.002* <0.0002*	<0.02* <0.002* <0.0002*
	terrestrial subchronic NOEL mg/kg/d	≥1000	100-<1000	10-<100	1-<10	<1*	<1*
	chronic NOEL mg/kg/d	≥500	50-<500	5-<50	0.5-<5	<0.5* *in one genus	<0.5* *in different genera
Sublethal Effects, Plants	Water, mg/L Air, mg/m³ Soil, mg/kg						
	% Growth Reduction: ≤5 (=NOAEL)						
	water	>10	>1-10	>0.1-1	>0.01-0.1	0.001-0.01	<0.001
	air	>100	>10-100	>1-10	>0.1-1	0.01-0.1	<0.01
	soil	>100	>10-100	>1-10	>0.1-1	0.01-0.1	<0.01
	>5-50(=EC_{50})						
	water	>100	>10-100	>1-10	>0.1-1	0.01-0.1	<0.01
	air	>1000	>100-1000	>10-100	>1-10	0.1-1	<0.1
	soil	>1000	>100-1000	>10-100	>1-10	0.1-1	<0.1
	>50						
	water	>1000	>100-1000	>10-100	>1-10	0.1-1	<0.1
	air	>10000	>1000-10000	>100-1000	>10-100	1-10	<1
	soil	>10000	>1000-10000	>100-1000	>10-100	1-10	<1
Sublethal Effects, Mammals*	oral NOEL mg/kg/day	>1000	>100-1000	>10-100	>1-10	>0.1-1	≤0.1
	inhal. NOEL mg/m³	>3000	>300-3000	>30-300	>3-30	>0.3-3	≤0.3
Teratogenicity	mg/kg/day	no teratogenic effects, or teratogenic only at >1000	teratogenic or developmental anomalies at >50-1000	teratogenic or developmental anomalies at >10-50	teratogenic or developmental anomalies at >1-10	teratogenic at >0.1-1, without overt maternal toxicity	teratogenic at ≤0.1 without overt maternal toxicity
Carcinogenicity	human and animal bioassay data	no tumours in adequate studies on at least two species, and does not interact with genetic material	tumours in only one animal species, negative results in others	causes benign tumours in more than one species, and does not interact with genetic material; promotor only; or causes cell transformation in vitro only (negative evidence in vivo)	tumourigenic in bioassays at doses causing metabolic enzyme saturation, or associated with lesions that predispose to tumours. No interaction with genetic material	indirect-acting carcinogen, no interaction with genetic material	direct-acting carcinogen that interacts with genetic material

* Note: The Sublethal Effects, Mammals criteria are based on studies of ≥90 days duration. If only shorter-term subchronic studies are available, the data are modified as follows, for scoring purposes:

Study duration 28-89 days - divide result by 10;
Study duration ≤28 days - divide result by 100.

monitoring program, and the cutoff values used to develop the EMPPL were more inclusive than those that would be appropriate for a bans/phase-outs initiative. The criteria used to define "persistent" and "bioaccumulative" for the EMPPL were retained for this exercise since they were consistent with precedents established by the IJC, by the Revised Great Lakes Water Quality Agreement and by best professional judgement.

The toxicity criteria were established as follows. Examining the scores for a set of approximately 650 substances assessed for MISA, it was determined that selecting a toxicity score of 10 would designate the most hazardous 10-15% of substances that were acutely lethal, chronically/subchronically toxic or teratogenic.

For carcinogenicity, substances were listed if they had been designated as human or animal carcinogens by the International Agency for Research on Cancer (IARC) or by the U.S. EPA.

The listing criteria resulted in the selection of a reasonably sized list of substances of highest concern from the point of view of persistence, bioaccumulation and toxicity.

5.2 Specific Criteria

The specific criteria used to list a substance are as follows. These are derived from the criteria provided in *The Ontario Ministry of the Environment Scoring System*:

I. Persistence

A substance is considered to be persistent if its half-life in water, sediment, soil or sludge exceeds 50 days. Soil and sludge are used as surrogates for sediment. Metals are considered to be persistent in all media.

II. Bioaccumulation

A substance is considered bioaccumulative if its fish bioconcentration factor (BCF) exceeds 500. In the absence of a BCF, the logarithm of the substance's octanol:water partitioning coefficient (log k_{ow}) is used to estimate bioconcentration potential. In the latter case, a substance is considered bioaccumulative if its log k_{ow} exceeds 4.0 but does not exceed 7.0. Note that log k_{ow} was not used to estimate the BCF for polycyclic aromatic hydrocarbons since for these substances log k_{ow} does not correlate well with BCF.

III. Toxicity

A substance is considered toxic if it meets any of the following criteria:

a) Acute Lethality

Aquatic LC_{50}	≤0.1 mg/L, or
Oral LD_{50}	≤0.5 mg/kg, or
Dermal LD_{50}	≤0.5 mg/kg, or
Inhalation LC_{50}	≤1.5 mg/m^3

b) Chronic/Subchronic Toxicity

Aquatic Biota:

EC_{50}	≤0.02 mg/L, or
MATC	≤0.002 mg/L, or
NOAC	≤0.0002 mg/L,

in different genera

Terrestrial Non-Mammals:

Subchronic Exposure: effects at ≤1 mg/kg, or
Chronic Exposure: effects at ≤0.5 mg/kg,
in different genera

Mammals:

Exposure ≥90 days: oral NOAEL ≤0.1 mg/kg or inhalation NOAEC ≤0.3 mg/m^3; or

Exposure 28-<90 days: oral NOAEL ≤0.01 mg/kg, or inhalation NOAEC ≤0.03 mg/m^3

Plants:

Aqueous medium:
NOAEL or ≤5% effect @<0.001 mg/L;
EC_{50} or >5-50% effect @<0.01 mg/L;
>50% effect @<0.1 mg/L;

Air medium:
NOAEL or ≤5% effect @<0.01 mg/m^3;
EC_{50} or >5-50% effect @<0.1 mg/m^3;
>50% effect @<1 mg/m^3;

Soil medium:
NOAEL or ≤5% effect @<0.01 mg/kg;
EC_{50} or >5-50% effect @<0.1 mg/kg;
>50% effect @<1 mg/kg.

c) Teratogenicity

Teratogenic effects observed without overt maternal toxicity at maternal exposures ≤0.1 mg/kg/day (or equivalent inhalational or dermal dose) during organogenesis.

d) Carcinogenicity

Human or animal carcinogen according to IARC or U.S. EPA classification, *i.e.* classified by IARC as a Group 1, 2A or 2B carcinogen or by the U.S. EPA as a Group A, B1 or B2 carcinogen.

6 Sources of Environmental Fate and Toxicity Information

For each substance considered, the information contained in the CESARS* database and in the Hazardous Contaminants Branch's assessment files was utilized. These files contain hazard assessments of environmental contaminants prepared by the Hazardous Contaminants Branch in support of Ministry programs, as well as chemical evaluations produced by the Michigan Department of Natural Resources. The assessments are based upon information obtained from an extensive range of sources including on-line factual and bibliographic databases. Where persistence and bioaccumulation data were lacking, such data were sought out and retrieved from various sources. In addition, all key information was reviewed and verified prior to the preparation of the final list. The reviews of persistence/bioaccumulation and toxicity data are documented in this report as Appendix 'A'.

7 The Primary List of Candidate Substances for Bans or Phase-Outs

Those substances identified in Ontario surface water or identified in effluent to receiving waters that meet or exceed the criteria described in Section 5.2 above are considered to be persistent, bioaccumulative and toxic. These substances are to be given first consideration as candidates for bans or phase-outs. These substances appear on the Primary List (Table 1.7). An expanded list showing the Ontario Ministry of the Environment Scoring System scores for each substance is provided in Appendix 'B'.

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* Chemical Evaluation Search and Retrieval System, a comprehensive database containing information on environmental contaminants maintained jointly by the Ontario Ministry of the Environment and the Michigan Department of Natural Resources.

Table 1.7: Primary List of Candidate Substances for Bans or Phase-Outs

CAS Number	Substance Name
120-12-7	anthracene
7440-38-2	arsenic
50-32-8	benzo[*a*]pyrene
191-24-2	benzo[*ghi*]perylene
56-55-3	benz[*a*]anthracene
50-29-3*	DDT (+ DDD & DDE)
106-46-7	1,4-dichlorobenzene (paradichlorobenzene)
91-94-1	3,3'-dichlorobenzidine
60-57-1	dieldrin
118-74-1	hexachlorobenzene
319-84-6	α-1,2,3,4,5,6-hexachlorocyclohexane
58-89-9	γ-1,2,3,4,5,6-hexachlorocyclohexane
7439-97-6	mercury
2385-85-5	mirex
87-86-5	pentachlorophenol
198-55-0	perylene
85-01-8	phenanthrene
n/a	polychlorinated biphenyls
n/a	polychlorinated dibenzo-p-dioxins and -furans
8001-35-2	toxaphene
688-73-3	tributyl tin

* CAS # for p,p'-DDT

Note that the Primary List contains six of the seven non-pesticide substances on the IJC Critical Pollutants List. The exception, alkylated lead, is not bioaccumulative according to the criterion selected (tetraethyl lead appears on the Secondary List, Group "A"). Note also that all of the pesticides on the IJC list have been effectively banned in Ontario except for dieldrin which has minor use as a structural termiticide.

Factsheets are provided in Section 10 of this report for each substance on the Primary List, containing summarized data on their uses, environmental fate and toxicity.

8 The Secondary List of Candidate Substances for Bans or Phase-Outs

The Secondary List (Table 1.8) is a second-tier list of candidate substances. These substances are to be considered as candidates for bans, phase-outs or reductions subsequent to the consideration of the substances on the Primary List. It has been divided into three groups as follows:

a) **Secondary List, Group "A"**

These are substances that meet or exceed the toxicity criteria used to establish the Primary List, and are either persistent or bioaccumulative but not both;

b) **Secondary List, Group "B"**

These substances are persistent and bioaccumulative, and have a toxicity hazard rating one level below that used as criteria for listing on the Primary List. Specifically, these substances received MOE Scoring System toxicity hazard scores of 8 (as opposed to 10) for any of the toxic endpoints considered;

c) **Secondary List, Group "C"**

These substances are either persistent or bioaccumulative, but not both, and have a toxicity hazard rating one level below that used as criteria for listing on the Primary List. Specifically, these substances received MOE Scoring System toxicity hazard scores of 8 (as opposed to 10) for any of the toxic endpoints considered.

An expanded list showing the Ontario Ministry of the Environment Scoring System scores for each substance is provided in Appendix 'B'.

Table 1.8: Secondary List of Candidate Substances for Bans or Phase-Outs

Group A

CAS Number	Substance Name
205-99-2	benzo[*b*]fluoranthene
192-97-2	benzo[*e*]pyrene
205-82-3	benzo[*j*]fluoranthene
207-08-9	benzo[*k*]fluoranthene
7440-41-7	beryllium
117-81-7	bis(2-ethylhexyl)phthalate
7440-43-9	cadmium
67-66-3	chloroform
7440-47-3	chromium (Cr^{+6})
218-01-9	chrysene
7440-50-8	copper
189-55-9	dibenzo[*a,i*]pyrene
194-59-2	7*H*-dibenzo[*c,g*]carbazole
226-36-8	dibenz[*a,h*]acridine
224-42-0	dibenz[*a,j*]acridine
57-97-6	7,12-dimethylbenz[*a*]anthracene
42397-65-9	1,*3*-dinitropyrene
123-91-1	1,*4*-dioxane
122-66-7	1,2-diphenylhydrazine
106-93-4	ethylene dibromide
77-47-4	hexachlorocyclopentadiene
193-39-5	indeno[1,2,3-*cd*]pyrene
7439-92-1	lead
129-00-0	pyrene
7440-22-4	silver (free ion)
100-42-5	styrene
58-90-2	2,3,*4*,6-tetrachlorophenol
78-00-2	tetraethyllead
62-56-6	thiourea
7440-61-1	uranium
7440-66-6	zinc

Group B

CAS Number	Substance Name
7429-90-5	aluminum
108-90-7	chlorobenzene
87-68-3	hexachlorobutadiene
67-72-1	hexachloroethane
608-93-5	pentachlorobenzene
95-95-4	2,*4*,5-trichlorophenol
115-86-6	triphenyl phosphate

Group C

CAS Number	Substance Name
7005-72-3	4-chlorophenyl phenyl ether (1-chloro-4-phenoxybenzene)
1945-53-5	palustric acid
7782-49-2	selenium
634-90-2	1,2,3,5-tetrachlorobenzene
2539-17-5	tetrachloroguaiacol
4901-51-3	2,3,*4*,5-tetrachlorophenol
87-61-6	1,2,3-trichlorobenzene
25155-23-1	trixylyl phosphate

9 Towards a Multimedia List

As mentioned in Section 1, the initial bans or phase-outs list resulting from the evaluation of aquatic contaminants is envisioned as the first building block for a multimedia bans or phase-outs list. The multimedia list will include additional pesticides and substances that are persistent in air, primarily released in emissions to air and primarily released directly to land. Note however that to a great extent the initial list is already a multimedia list since many of the substances evaluated to produce it appear in or are discharged to not only water but also air, land, soil and/or sediment. Substances designated for banning or phasing out would also be regulated on a multimedia basis.

The selection criteria used to create the initial list are also applicable to solid waste and air emission evaluation. In the latter case, an additional criterion will be considered to address effects on atmospheric chemistry leading to secondary hazards, *e.g.* the depletion of ozone by CFC-derived free radicals.

10 Factsheets for Substances on the Primary List

A set of factsheets follow, containing summarized data on the uses, environmental fate and toxicology of the substances on the Primary List.

Anthracene

1. Basic Description

CAS#: 120-12-7
Chemical type: Polycyclic aromatic hydrocarbon (PAH)
Molecular weight: 178.22
Solubility: 0.073 mg/l
Vapour pressure: 3.7×10^{-6} mm Hg (25°C)
Log Kow: 4.45

2. Sources and Uses

Present in coal tar, constituent of crude oil heavy fractions, potentially produced in petroleum refining processes, byproduct of coking processes (anaerobic coal distillation), produced when organic material is burned. Used in the manufacture of anthraquinone dyes and alizarin dyes.

3. Toxicity and Environmental Fate

Anthracene is a polycyclic aromatic hydrocarbon (PAH) which has been shown to bioaccumulate in freshwater fish tissues. Bioconcentration factors have been reported as being 480-910X. In general, PAHs are thought to be rapidly metabolized by fish but not by freshwater invertebrates which absorb and bioaccumulate them. Anthracene is highly persistent in soil (half-life 50 days to 1.26 years) and sediment (half-life up to 16.5 weeks) but is not persistent in surface water or air.

Anthracene displays very high acute toxicity to aquatic organisms including fish and freshwater invertebrates.

Arsenic

1. Basic Description

CAS# 7440-38-2
Chemical Type: Metal (inorganic salts)
Molecular weight: 74.92
Solubility: Insoluble except in nitric acid

2. Sources and Uses

A naturally occurring element, with a concentration in the earth's crust of 0.0005%. An impurity in crude oil and iron ore. Used in metallurgy for hardening copper, lead and alloys, and in the manufacture of certain types of glass. Formerly used as a pesticide. A radioactive isotope, ^{76}As, is used as a tracer in pharmacological studies.

3. Toxicity and Environmental Fate

Arsenic has been shown to strongly bioaccumulate in fish tissues (700X) and in freshwater molluscs (650X). As an elemental metal it is expected to be highly persistent in all media.

Arsenic appears to have relatively moderate aquatic and mammalian toxicity. A major concern with arsenic compounds is their strong mutagenic and carcinogenic potential. Arsenic appears on the CEPA Priority Toxic Substances List.

Benzo[*a*]pyrene

1. Basic Description

CAS#: 50-32-8
Chemical type: Polycyclic aromatic hydrocarbon (PAH)
Molecular weight: 252.3
Solubility: 0.004 mg/l
Vapour pressure: 7.3×10^{-10} mm Hg (25°C)
Log Kow: 6.34

2. Sources and Uses

Present in coal tar, constituent of crude oil heavy fractions, potentially produced in petroleum refining processes, byproduct of coking processes (anaerobic coal distillation), produced when organic material is burned. Used as a carcinogenic agent in medical research.

3. Toxicity and Environmental Fate

The PAH benzo[*a*]pyrene (B[*a*]P) has been shown to strongly bioaccumulate in fish tissues (bioconcentration factors have been reported as 479, 490, or 2657X depending on tissue/species type). It is highly persistent in soil (half-life 57 days to 1.45 years) and, based on analogy to other PAHs, persistent in sediments (expected biodegradation half-life greater than 7000 hours). It is not persistent in air or surface water.

As with the PAH anthracene, B[*a*]P demonstrates very high acute aquatic toxicity to freshwater fish and invertebrates such as *Daphnia* sp. Chronic aquatic toxicity is also relatively high. The International Agency for Research on Cancer (IARC) has concluded that B[*a*]P is carcinogenic to experimental animals and that it is a probable human carcinogen. B[*a*]P appears on the IJC Critical Pollutants List and the CEPA Priority Toxic Substances List.

Benzo[*g,h,i*]perylene

1. Basic Description

CAS#: 191-24-2
Chemical type: Polycyclic aromatic hydrocarbon (PAH)
Molecular weight: 276.3
Solubility: 0.26 µg/l
Vapour pressure: 1.1×10^{-11} mm Hg (25°C)
Log Kow: 6.51

2. Sources and Uses

Present in coal tar, constituent of crude oil heavy fractions, potentially produced in petroleum refining processes, byproduct of coking processes (anaerobic coal distillation), produced when organic material is burned.

3. Toxicity and Environmental Fate

B[*g,h,i*]P is a PAH which has been reported to bioaccumulate in freshwater fish tissues (6816X in minnows) and in invertebrates. It is highly persistent in soils (half-life 590-650 days) and, by analogy to other PAHs, expected to be very persistent in sediments (expected half-life greater than 7000 hours). The available data indicate it is not persistent in air. The persistence in water is not known.

As with several PAHs, B[*g,h,i*]P may have very high acute aquatic toxicity to freshwater invertebrates.

Benz[*a*]anthracene

1. Basic Description

CAS#: 56-55-3
Chemical type: Polycyclic aromatic hydrocarbon (PAH)
Molecular weight: 228.3
Solubility: 0.0057 mg/l
Vapour pressure: 2.93×10^{-6} Pa (20°C)
Log Kow: 5.61

2. Sources and Uses

Present in coal tar, constituent of crude oil heavy fractions, potentially produced in petroleum refining processes, byproduct of coking processes (anaerobic coal distillation), produced when organic material is burned.

3. Toxicity and Environmental Fate

B[*a*]A has been reported to strongly bioaccumulate (bioconcentration factor reported to be 347, 850, or 10,000X) in two species of freshwater fish. It is highly persistent in soil (half-life 102 days to 1.86 years) and in sediments (expected half-life may be greater than 7000 hours). It is not persistent in water or air.

As with a number of PAHs, B[*a*]A has been shown to have very high acute toxicity to aquatic organisms such as Fathead minnows and *Daphnia* sp. IARC has concluded that B[*a*]A is carcinogenic to animals and is a probable human carcinogen.

DDT (+ DDD & DDE)

1. Basic Description

CAS#: p,p'-DDT 50-29-3, p,p'-DDD 72-54-8, p,p'-DDE 72-55-9
Chemical type: organochlorine
Molecular weight: DDT 354.5, DDD 320.5, DDE 318.0
Solubility: DDT 0.0034 mg/l, DDD 0.160 mg/L, DDE 0.014 mg/L (20°C)
Vapour pressure: DDT 0.188 mm Hg (20°C),
DDD 1.02×10^{-6} mm Hg (30°C), DDE 6.5×10^{-6} mm Hg (20°C)
Log Kow: DDT 3.9-6.2, DDD 6.20, DDE 4.3-7.0

2. Sources and Uses

Historically DDT has seen widespread use in North America and the world as a pesticide. It was banned from use in the United States in 1972 and officially banned in Ontario in 1989. DDD and DDE are metabolites and contaminants of DDT.

3. Toxicity and Environmental Fate

DDT is extremely persistent in soils, sediments, and water with half-lives reported in the range of 7 days to greater than 30 years. It has been shown to bioaccumulate in many tissue types including fish tissues at concentration factors up to 363,000X. It demonstrates extremely high acute and chronic aquatic toxicity, very high mammalian chronic toxicity, and there is considerable evidence of teratogenicity, mutagenicity, and carcinogenicity.

DDD strongly bioaccumulates in fish tissues (bioconcentration factors have been reported in the range 933 to 6500X). It is highly persistent in soil, sediments, and water with half-lives reported to be as high as 190 years. DDD is extremely acutely toxic to many aquatic organisms including freshwater fish and invertebrates.

DDE is highly persistent in soil and sediments but not in water. Half-lives have been reported to be up to 15 years in soils and up to 1100 days in sediments. As with DDT and DDD, DDE is highly bioaccumulative with concentration factors in fish tissues as high as 50,000X. DDE displays very high toxicity to a wide variety of aquatic vertebrates and invertebrates.

1,4-Dichlorobenzene (para-dichlorobenzene)

1. Basic Description

CAS# 106-46-7
Chemical Type: Chlorinated organic
Molecular weight: 147.01
Solubility: 87 mg/l
Vapour pressure: 1.76 mm Hg (25°C)
Log Kow: 3.52

2. Sources and Uses

Contaminant of commercial grade ortho-dichlorobenzene, a commonly used deodourizing compound. Insecticidal fumigant, miticide; used domestically against clothes moths.

3. Toxicity and Environmental Fate

1,4-dichlorobenzene has been shown to have a bioconcentration factor in rainbow trout as high as 1400X depending on stage and tissue type. It is highly persistent in soils (half-life 1 to 6 months) and sediments (based on monitoring data). It is moderately persistent in air (half-life 8.4 to 84 days) and not persistent in water.

1,4-dichlorobenzene is a strong mutagen and carcinogen (IARC). It appears on the CEPA Priority Toxic Substances List.

3,3'-Dichlorobenzidine

1. Basic Description

CAS#: 91-94-1
Chemical Type: Chlorinated organic
Molecular Weight: 253.13
Solubility: 3.1 mg/l
Vapour pressure: 4.2×10^{-7} mm Hg (25°C)
Log Kow: 3.56

2. Sources and Uses

Used to manufacture azo dyes and as an intermediate in synthesizing benzidine yellow pigments.

3. Toxicity and Environmental Fate

3,3'-dichlorobenzidine may bioaccumulate in fish tissues in the range 114 to 610X. It is highly persistent in soils (half-life 1 to 6 months) but not in water or air.

3,'3-dichlorobenzidine is a demonstrated animal carcinogen (IARC). It appears on the CEPA Priority Toxic Substances List.

Dieldrin

1. Basic Description

CAS#: 60-57-1
Chemical type: organochlorine
Molecular weight: 380.9
Solubility: 0.200 mg/l (25°C)
Vapour pressure: 7.8×10^{-7} mm Hg (25°C)
Log Kow: 5.1-6.2

2. Sources and Uses

Dieldrin is a pesticide which is no longer being manufactured nor imported in Canada or the United States. In Ontario, it sees minor use as a structural termiticide (<400 kg/yr) but current stocks will not be replenished.

3. Toxicity and Environmental Fate

Dieldrin is highly persistent in soil and water with half-lives reported in the range of 175 days to 3 years. It is expected to bioaccumulate in the food chain with concentration factors in freshwater fish tissue reported as high as 77,000X. Dieldrin displays very high acute aquatic and chronic mammalian toxicity.

Hexachlorobenzene

1. Basic Description

CAS#: 118-74-1
Chemical Type: Chlorinated organic
Molecular weight: 284.8
Solubility: 0.0062 mg/l
Vapour pressure: 1.9×10^{-5} mm Hg (25°)
Log Kow: 5.31

2. Sources and Uses

Used to synthesize other organic chemicals and as a fungicide.

3. Toxicity and Environmental Fate

Hexachlorobenzene has been shown to bioaccumulate in fish in the range 1160 to 35,000X. It is highly persistent in soils (half-life 2.7 to 5.7 years), sediments, and in air (photo-oxidation half-life 156.4 days to 4.2 years) but not in water.

Hexachlorobenzene demonstrates relatively high chronic toxicity in mammals and is a known animal carcinogen (IARC). It appears on the IJC Critical Pollutants List and the CEPA Priority Toxic Substances List.

α-Hexachlorocyclohexane

1. Basic Description

CAS#: 319-84-6
Chemical Type: Chlorinated organic
Molecular weight: 285
Solubility: 2 mg/l
Vapour pressure: 0.02 mm Hg (20°C)
Log Kow: 3.81

2. Sources and Uses

Byproduct of organic chemical processes, constituent of technical-grade hexachlorocyclohexane, contaminant in Lindane (γ-hexachlorocyclohexane) formulations.

3. Toxicity and Environmental Fate

α-HCH has been shown to bioaccumulate in freshwater fish tissues in the range 500 to 1216X. It is highly persistent in soils (half-life 7 to 135 days), and may persist in surface water (hydrolysis half-life estimated to be 500 days to 2 years). It is not persistent in air. Its persistence in water is not known.

IARC has determined that there is sufficient evidence that α-HCH is an animal carcinogen.

γ-Hexachlorocyclohexane (Lindane)

1. Basic Description

CAS#: 58-89-9
Chemical type: Chlorinated organic
Molecular weight: 290.82
Solubility: 7 mg/l
Vapour pressure: 0.03 mm Hg (20°C)
Log Kow: 3.72

2. Sources and Uses

Byproduct of organic chemical processes, constituent of technical-grade hexachlorocyclohexane; insecticide; used in medicine as a pediculicide and scabicide; and as a veterinary ectoparasiticide.

3. Toxicity and Environmental Fate

γ-HCH may strongly bioaccumulate in freshwater fish tissues in the range 180 to 1613X and is highly persistent in soils (half-life 5.9 days to 2 years), sediments (half-life 4 to 5 years), and in water (hydrolysis half-life 13.8 to 240 days) but not in air.

γ-HCH has very high acute toxicity to fish and other aquatic organisms and relatively high chronic toxicity to mammals. It is a strong mutagen and a demonstrated carcinogen in animals.

Mercury

1. Basic Description

CAS#: 7439-97-6
Chemical Type: Metal
Molecular weight: 200.59
Solubility: 20 µg/l

2. Sources and Uses*

Naturally occurring in coal and mineral ores. Used in barometers, thermometers, hydrometers, pyrometers; in mercury arc lamps producing ultraviolet rays; in switches, fluorescent lamps; in mercury boilers; manufacture of all mercury salts, mirrors; as a catalyst in the oxidation of organic compounds; extracting gold and silver from ores; making amalgams, electric rectifiers, mercury fulminate; also in dentistry; in determining N by Kjeldahl method, for Millon's reagent; as cathode in electrolysis, electroanalysis, and many other uses. Also in pharmaceuticals, agricultural chemicals, anti-fouling paints.

3. Toxicity and Environmental Fate

Bioconcentration factors for mercury in fish tissues have been reported in the range 4000 to 85,000. As an elemental metal it is considered to be extremely persistent in all media.

Mercury displays very high acute toxicity to fish and other aquatic organisms. It is also capable of severe reproductive and teratogenic effects in mammals. Mercury appears on the IJC Critical Pollutants List and the CEPA Priority Toxic Substances List.

[* - Uses as cited in *The Merck Index Online*]

Mirex

1. Basic Description

CAS#: 2385-85-5
Chemical type: organochlorine
Molecular weight: 545.5
Solubility: 0.20 mg/l (24°C)
Log Kow: 5.83

2. Sources and Uses

Mirex has historically been used as a flame retardent, antioxidant, antifouling additive in paints, and as an insecticide (particularly to control fireants in the U.S.). Mirex is not registered for use in Canada.

3. Toxicity and Environmental Fate

Mirex is strongly persistent in soils and sediments where it may be expected to be bioavailable for up to 600 years. It has been shown to bioconcentrate in fish tissues in the range of 7300 to 28,000X. Mirex displays high aquatic toxicity to both fish and plant life as well as exhibiting high chronic mammalian toxicity, teratogenicity, and carcinogenicity.

Pentachlorophenol

1. Basic Description

CAS#: 87-86-5
Chemical type: Chlorinated organic
Molecular weight: 266.32
Solubility: 14 mg/l
Vapour pressure: 1.1 x 10^{-4} mm Hg (20°C)
Log Kow: 5.12

2. Sources and Uses

Present in effluent from pulp mills using previously treated wood chips. Used in preserving wood, wood products, starches, dextrins, glues; used as an insecticide for termite control; pre-harvest defoliant; general herbicide.

3. Toxicity and Environmental Fate

Data from numerous studies indicates PCP is capable of bioconcentrating in the range of 251 to 5370X. It is moderately persistent in soil and air but may be highly persistent in sediments (half-life 42 days to 4.2 years). It is not persistent in water.

PCP demonstrates very high acute and chronic aquatic toxicity.

Perylene

1. Basic Description

CAS#: 198-55-0
Chemical type: Polycyclic aromatic hydrocarbon
Molecular weight: 252.3
Solubility: 0.0004 mg/l
Log Kow: 6.06

2. Sources and Uses

Present in coal tar, constituent of high-boiling-point petroleum fractions, potentially produced in petroleum refining processes, byproduct of coking processes (anaerobic coal distillation), produced when organic material is burned.

3. Toxicity and Environmental Fate

The bioconcentration factor for perylene in minnows has been reported as 1112X. Perylene is believed to be highly persistent in sediments based on analogy to other structurally similar PAHs (half-life expected to be greater than 7000 hours). No information is available on the persistence in air, water, or soils.

Perylene demonstrates very high acute aquatic toxicity to freshwater invertebrates (*Daphnia* sp.).

Phenanthrene

1. Basic Description

CAS#: 85-01-8
Chemical type: Polycyclic aromatic hydrocarbon (PAH)
Molecular weight: 178.2
Solubility: 1.29 mg/l
Vapour pressure: 0.016 Pa (25°C)
Log Kow: 4.46

2. Sources and Uses

Present in coal tar, constituent of crude oil heavy fractions, potentially produced in petroleum refining processes, byproduct of coking processes (anaerobic coal distillation), produced when organic material is burned. A disodium derivative is used as a dehalogenation reagent.

3. Toxicity and Environmental Fate

The PAH phenanthrene has been reported (in two species) to bioconcentrate in fish tissues in the range 1778-5225X. It may be highly persistent in soils (half-life 16 to 200 days) and in water (photolysis half-life up to 69 days) but not in air. Persistence in sediments is not known.

As with a number of PAHs, phenanthrene demonstrates very high acute aquatic toxicity to freshwater invertebrates (*Daphnia* sp.).

Polychlorinated Biphenyls

1. Basic Description

CAS#: n/a
Chemical type:
Molecular weight: Aroclor 1242 (avg 266.5); Aroclor 1260 (avg 375.7)
Solubility: Aroclor 1242 (0.24 mg/l); Aroclor 1260 (0.0027 mg/l)
Vapour pressure: Aroclor 1242 (0.004 mm Hg (25°C)); Aroclor 1260 (0.0004 mm Hg (25°C))
Log Kow: Aroclor 1242 (4.11); Aroclor 1260 (6.03)

2. Sources and Uses*

Once widely used industrial chemicals whose high stability contributed to both their commercial usefulness and their long-term deleterious environmental and health effects. Used in electrical capacitors, electrical transformers, vacuum pumps, gas-transmission turbines. Formerly used in U.S. as hydraulic fluids, plasticizers, adhesives, fire retardants, wax extenders, dedusting agents, pesticide extenders, inks, lubricants, cutting oils, in heat transfer systems, carbonless reproducing paper.

3. Toxicity and Environmental Fate

PCBs have been reported to bioconcentrate in fish tissues in the range 1076 to over 200,000X. They are extremely persistent in sediments and in water.

PCBs demonstrate very high acute and chronic toxicity to aquatic organisms, are well established as animal carcinogens, and are probable human carcinogens (IARC). PCBs appear on the IJC Critical Pollutants List.

[* - Sources and uses as cited in *The Merck Index Online*]

Polychlorinated dibenzo-p-dioxins and furans

1. Basic Description

CAS#: n/a
Chemical type:
Molecular weight: 322 (2,3,7,8 TCDD); 306 (2,3,7,8 TCDF)
Solubility: 2×10^{-4} mg/l (2,3,7,8 TCDD)
Vapour pressure: 3.46×10^{-9} (30°C)(2,3,7,8 TCDD); 2×10^{-5} (25°C)(2,3,7,8 TCDF)
Log Kow: 6.15-7.28 (2,3,7,8 TCDD); 5.82 (2,3,7,8 TCDF)

2. Sources and Uses

Contaminant of 2,4,5-trichlorophenol and 2,4,5-trichlorophenoxyacetic acid (the herbicide "2,4,5-T"); formed during the manufacture of trichlorophenols; formed in chlorine bleaching of pulp (in kraft process paper mills); produced during regeneration of catalysts in petroleum refining operations; may be formed when organic material is burned if chlorine is available.

3. Toxicity and Environmental Fate

PCDDs and PCDFs have been shown to bioaccumulate in fish tissues in the range of 240 to 26,000X. They are extremely persistent in soil (half-life may be greater than 10 years), water (half-life 1.15 to 1.62 years) and in sediments (half-life greater than 1 year) but not in air.

PCDDs and PCDFs have been shown to have very high acute and chronic oral toxicity in many species, very high chronic aquatic toxicity, and very strong teratogenic and carcinogenic potential. PCDDs and PCDFs appear on the IJC Critical Pollutants List and the CEPA Priority Toxic Substances List.

Toxaphene

1. Basic Description

CAS#: 8001-35-2
Chemical type: organochlorine
Molecular weight: 414
Vapour pressure: 0.2-0.4 mm Hg (25°C)
Log Kow: 2.9-3.3

2. Sources and Uses

Toxaphene has been used as a vegetable crop insecticide, herbicide, and to control animal ectoparasites. Most uses of toxaphene in the U.S. were banned in 1982. It is not registered for use in Canada.

3. Toxicity and Environmental Fate

Toxaphene is highly persistent in soils and in water where the half-life may be as high as 20 years. It has also been shown to strongly bioaccumulate with concentration factors in fish tissue reported as high as 100,000X. It displays extremely high acute and chronic aquatic toxicity and there is considerable evidence of teratogenicity, mutagenicity, and carcinogenicity.

Tributyl tin

1. Basic Description

CAS#: 688-73-3
Chemical type: Metal-organic
Molecular weight: 291.09
Log Kow: 3.7

2. Sources and Uses

Used as a catalyst for polymerization reactions, in hydrostannation reactions, as a reducing agent, a dehalogenating agent and as an antifouling additive in marine paints.

3. Toxicity and Environmental Fate

Tributyl tin has been shown to bioconcentrate in fish tissues (in two species) in the range of 257-5020X depending on tissue type. It is highly persistent in soils (half-life 15 to 20 weeks), water (half-life up to 2 years) and in sediments (half-life greater than 200 days). The persistence in air is not known.

Tributyl tin displays very high acute and chronic toxicity to aquatic organisms and is very toxic to aquatic vegetation. Organotin compounds appear on the CEPA Priority Toxic Substances List.

Part II

Loadings and Environmental Impacts of Substances on the Primary List

1 Purpose of this Part of the Report

As discussed in Part I, 21 highly hazardous substances have been selected and designated as the primary candidate substances for bans or phase-outs. The purpose of this part of the report is to:

1) identify the Primary List candidate substances found in MISA industrial and municipal effluents;

2) summarize the total loadings of Primary List substances being discharged directly into Ontario surface waters from industrial and municipal point sources;

3) conduct a hazard evaluation of point source discharges of Primary List substances based on aquatic toxicity and potential use impairments; and

4) summarize receiving water impacts or beneficial use impairments that have been identified in the Ontario Great Lakes watershed for the 21 Primary List substances.

2 Primary List Substances found in MISA Effluent Discharges

The MISA industrial monitoring database and the 37 Municipal Water Pollution Control Plants (WPCPs) study database were screened for the presence of candidate substances on the Primary List (Table 2.1).

For the purpose of this exercise, only quality-controlled and quality-assured effluent monitoring data were assessed. Industrial monitoring data were not available for 3,3'-dichlorobenzidine, dieldrin, alpha-hexachlorocyclohexane (alpha-BHC), gamma-hexachlorocyclohexane (lindane or gamma-BHC), mirex, toxaphene, and tributyltin. Municipal monitoring data were not available for benzo[*g*,*h*,*i*]perylene, 3,3'-dichlorobenzidine, perylene, and tributyltin.

Fifteen highly hazardous substances on the primary list were found in MISA industrial or municipal sector effluents. Thirteen of these substances were found in industrial discharges and four (alpha-BHC, lindane, mercury, and PCBs) were found in municipal discharges.

The substances found included seven organochlorine compounds or chemical groups (1,4-dichlorobenzene, hexachlorobenzene, alpha-BHC, lindane, pentachlorophenol, polychlorinated biphenyls, polychlorinated dibenzo-p-dioxins or dibenzofurans), six polycyclic aromatic hydrocarbons (anthracene, benz[*a*]anthracene,

TABLE 2.1 PRIMARY LIST SUBSTANCES FOUND IN EFFLUENTS

PARAMETER	OCM	IRON & STEEL	INORGANIC	PETROLEUM	PULP & PAPER	MINING	METAL CASTING	MUNICIPAL WPCPs
arsenic	present	present	present	present		present	present	
DDT & metabolites								
1,4-dichlorobenzene (paradichlorobenzene)	present		present					
3,3'-dichlorobenzidine								
Dieldrin								
hexachlorobenzene	present	present	present			present		
alpha-hexachlorocyclohexane								present
gamma-hexachlorocyclohexane (Lindane)								present
mercury	present	present	present	present	present	present	present	present
mirex								
pentachlorophenol					present			
PCB (TOTAL)	present		present				present	present
PCDD-F/ 2,3,7,8-tetrachlorodibenzo-p-dioxin	present				present			
PCDD-F/ TOTAL tetrachlorodibenzo-p-dioxin (TCDD)	present		present		present			
PCDD-F/ TOTAL tetrachlorodibenzofuran (TCDF)	present		present	present	present			
PCDD-F/ TOTAL pentachlorodibenzo-p-dioxin (P5CDD)	present		present		present			
PCDD-F/ TOTAL pentachlorodibenzofuran (P5CDF)	present		present	present	present			
PCDD-F/ TOTAL hexachlorodibenzo-p-dioxin (H6CDD)	present		present		present			
PCDD-F/ TOTAL hexachlorodibenzofuran (H6CDF)	present		present		present			
PCDD-F/ TOTAL heptachlorodibenzo-p-dioxin (H7CDD)	present		present	present	present			
PCDD-F/ TOTAL heptachlorodibenzofuran (H7CDF)	present		present		present			
PCDD-F/ TOTAL octachlordibenzo-p-dioxin (O8CDD)	present	present	present	present	present			
PCDD-F/ TOTAL octachlorodibenzofuran (O8CDF)	present	present	present		present			
PAH/ anthracene		present						
PAH/ benzo(g,h,i)perylene		present			present			
PAH/ benzo[a]pyrene		present						
PAH/ benz[a]anthracene		present						
PAH/ perylene		present						
PAH/ phenanthrene		present	present		present		present	
toxaphene								
tributyl tin								

LEGEND: * = Chemicals which are Bioaccumulative, Persistent and Toxic

All information obtained from staff of MISA Industrial and Municipal Sections

benzo[*g,h,i*]perylene, benzo[*a*]pyrene, perylene, and phenanthrene), and two metals or metalloids (arsenic and mercury).

The six persistent, bioaccumulative and highly toxic chemicals not found in industrial or municipal discharges were DDT and metabolites, 3,3'-dichlorobenzidine, dieldrin, mirex, toxaphene, and tributyl tin. It should be noted, however, that no monitoring data were available for 3,3'-dichlorobenzidine and tributyl tin. Also, DDT, mirex and toxaphene are not registered for use in Canada and use of dieldrin and tributyl tin are restricted.

3 Point Source Loadings of Primary List Substances

3.1 Industrial Inputs

The annual loadings of the 13 Primary List substances discharged by MISA industrial sectors are summarized in Table 2.2. These loadings should be regarded as preliminary upper bound estimates at this time. Also, loadings for the electric power sector are not available at this time.

The parameters exhibiting the highest total annual loadings were arsenic at 13,364 kg/year primarily because of inputs from the mining sector and phenanthrene at 665 kg/year primarily because of inputs from the pulp and paper sector. In general, total annual loadings of 1,4-dichlorobenzene, hexachlorobenzene, mercury, PCB, PCP, and other PAH compounds were 200 kg/year or less. Total inputs of dioxins and furans from the inorganic chemicals, pulp and paper, petroleum and the organic chemicals manufacturing sectors were estimated to be less than 0.2 kg/yr.

3.2 Municipal Water Pollution Control Plant Inputs

The measured annual loadings of the four Primary List substances discharged by municipal water pollution control plants (WPCPs) in 1987 were as follows:

mercury	- 1,587 kg/year
lindane	- 22 kg/year
PCBs	- 9 kg/year
alpha-BHC	- 1 kg/year.

The total loadings determined for these 37 WPCPs accounted for approximately 74 percent of the total Ontario flow of municipal wastewaters.

3.3 Summary of Point Source Loadings

Based on the available monitoring information, annual inputs of arsenic from point source discharges into Ontario surface waters are greater than 10,000 kg/year and annual inputs of mercury are greater than 1000 kg/year. For the sum of six PAH

TABLE 2.2 ANNUAL LOADINGS OF PRIMARY LIST CHEMICALS FOUND IN MISA INDUSTRIAL SECTOR EFFLUENTS (kg/year)*

PARAMETER	OCM ***	IRON & STEEL	INORGANIC **	PETROLEUM	PULP & PAPER	MINING	METAL CASTING	TOTAL
ARSENIC	15	301	109	185	-	12728	26	13364
1,4-DICHLOROBENZENE	177	-	2	-	-	-	-	179
HEXACHLOROBENZENE	3	2	0.2	-	-	2	-	7
MERCURY	105	7	34	0.8	15	33	6	200
PENTACHLOROPHENOL	-	-	-	-	32	-	-	32
PCB (TOTAL)	0.04	-	0.09	-	-	-	3.650	4
PCDD-F/ 2,3,7,8-TCDD	0.0009	-	-	-	0.002	-	-	0.003
PCDD-F/ TOTAL TCDD	0.0009	-	0.00002	-	0.01	-	-	0.01
PCDD-F/ TOTAL TCDF	0.002	-	0.02	0.003	0.03	-	-	0.06
PCDD-F/ TOTAL P5CDD	0.003	-	0.003	-	0.002	-	-	0.01
PCDD-F/ TOTAL P5CDF	0.005	-	0.01	0.003	0.005	-	-	0.02
PCDD-F/ TOTAL H6CDD	0.0010	-	0.003	-	0.003	-	-	0.007
PCDD-F/ TOTAL H6CDF	0.008	-	0.005	-	0.0030	-	-	0.02
PCDD-F/ TOTAL H7CDD	0.005	-	0.003	0.003	0.009	-	-	0.02
PCDD-F/ TOTAL H7CDF	0.007	-	0.00005	-	0.008	-	-	0.02
PCDD-F/ TOTAL O8CDD	0.01	0.002	0.02	0.008	0.028	-	-	0.07
PCDD-F/ TOTAL O8CDF	0.01	0.0004	0.0002	-	0.006	-	-	0.02
PAH/ ANTHRACENE	-	4	-	-	-	-	-	4
PAH/ BENZO(G,H,I)PERYLENE	-	44	-	-	-	-	-	44
PAH/ BENZO[A]PYRENE	-	79	-	-	-	-	-	79
PAH/ BENZ[A]ANTHRACENE	-	89	-	-	-	-	-	89
PAH/ PERYLENE	-	12	-	-	-	-	-	12
PAH/ PHENANTHRENE	-	21	46	-	562	-	35	665

LEGEND: * - THESE YEARLY LOADINGS REPRESENT THE UPPER BOUNDARY

** - SOURCE OF CHLORINATED DIBENZO-P-DIOXINS AND FURANS IN THE INORGANIC CHEMICALS SECTOR ARE UNKNOWN

*** - LOADINGS OF CHLORINATED DIBENZO-P-DIOXINS AND FURANS FOR ORGANIC CHEMICAL MANUFACTURING SECTOR INCLUDE ONLY THOSE FOR DOW CHEMICAL. DATA FROM OTHER PLANTS ARE INSUFFICIENT TO CALCULATE LOADINGS.

compounds, annual loadings are approximately 1000 kg/year and annual loadings of 1,4-dichlorobenzene are about 200 kg/year.

The measured annual loadings of pentachlorophenol, lindane, PCBs, hexachlorobenzene, and alpha-BHC were about 30, 20, 10, 10, and 1 kg/year, respectively. Annual inputs of polychlorinated dibenzo-p-dioxins and furans are less than 1 kg/year.

It was beyond the scope of this exercise to assess the ecological significance of the total loadings estimates and to predict the potential benefits of remedial control programs. Nonetheless, the loadings provide valuable information for further exposure assessments (e.g. mass-balance modelling) and environmental risk assessments of these highly hazardous substances.

If released into the environment, these persistent, bioaccumulative, and extremely toxic substances can bioconcentrate or accumulate in aquatic ecosystems to levels which are harmful to aquatic life and their consumers. Furthermore, anthropogenic inputs of these substances should be curtailed as the difference between tolerable natural background levels and harmful effects in the environment is exceptionally small. Ideally, to assure long-term protection of aquatic organisms and humans, any inputs of these substances should be eliminated.

4 Hazard Evaluation of MISA Effluents

The MISA industrial and municipal monitoring databases were used to conduct a preliminary chemical hazard evaluation of industrial waste streams based on concentrations and frequency of exceedances of ambient water quality criteria such as Provincial Water Quality Objectives or Guidelines (PWQO or PWQG) and Great Lakes Water Quality Agreement Specific Objectives (GLWQA specific objectives). Also, effluent concentrations were compared to aquatic toxicity data for laboratory populations exposed during short-term (acute) or long-term (chronic) studies.

This effluent hazard evaluation is a valuable screening technique because effluent concentrations that are several orders of magnitude above water quality objectives may have serious environmental impacts. Potential impacts may include harmful effects to aquatic life, loss of fish habitat, loss of beneficial uses of aquatic resources (e.g. recreation and water supplies), and increased costs for remediation.

This approach is consistent with a pollution prevention philosophy and commitments of the Province under the Great Lakes Water Quality Agreement. Also, discharging substances in highly toxic amounts will be prohibited in MISA Effluent Limit Regulations. A substance was considered to be discharged in highly toxic amounts if it entered the environment in a quantity or concentration that has an immediate or long-term harmful effect on aquatic organisms.

4.1 Results

The frequencies of exceedances of the various evaluation endpoints (e.g., PWQO times 10,000) are summarized in Table 2.3. The frequencies computed for each sector were based on at least 10 observations or analytical determinations. Comments on selected contaminants are provided below.

4.1.1 Arsenic

Although arsenic was occasionally found in industrial sector effluents, only the mining sector exhibited concentrations of 1000 µg/L or more (Table 2.3). Concentrations of arsenic in water at or above 1000 µg/L are considered to be highly toxic to aquatic life based on acute and chronic toxicity data (Spehar and Fiandt, 1986; Lima *et al.*, 1984; Spehar *et al.*, 1980). Also, this level of arsenic corresponds to 10 times the PWQO or 20 times the GLWQA specific objective.

4.1.2 1,4-Dichlorobenzene (1,4-DCB)

Concentrations of 1,4-dichlorobenzene found in effluents from the organic chemical manufacturing sector (OCM) and the inorganic chemicals sector were less than 40 µg/L or 10 times the PWQO (Table 2.3). Therefore, analysis of MISA effluents did not reveal the existence of highly toxic discharges of 1,4-DCB. 1,4-DCB is highly toxic to aquatic life when ambient concentrations exceed 2000 µg/L in short-term exposures or 400 µg/L in long-term exposures (OMOE, 1984).

4.1.3 Alpha-Hexachlorocyclohexane (Alpha-BHC)

Alpha-BHC was occasionally found in municipal discharges and concentrations did not exceed 0.05 µg/L (Table 2.3). Discharges of alpha-BHC at 100 ug/L are considered to be highly toxic to aquatic biota based on chronic toxicity data for waterborne exposures (Canton *et al.*, 1975; Canton and Slooff, 1977).

4.1.4 Gamma-Hexachlorocyclohexane (Lindane)

Lindane was often found in municipal discharges and concentrations did not exceed 0.1 µg/L (Table 2.3). Discharges of lindane at 0.3 µg/L are considered to be highly toxic to aquatic biota based on acute toxicity data for waterborne exposures (Sanders, 1972).

4.1.5 Hexachlorobenzene (HCB)

Concentrations of hexachlorobenzene exceeded the PWQO by 100 times or more in effluents from the inorganic chemicals sector (Table 2.3). The maximum

TABLE 2.3 SUMMARY OF MISA EFFLUENT DISCHARGE DATA AND FREQUENCY OF EXCEEDANCES OF VARIOUS HAZARD ASSESSMENT END-POINTS

ANALYTICAL PARAMETER	ASSESSMENT END-POINT	CONCENTRATION (ug/L)	OCM	IRON & STEEL	INORGANIC	PETROLEUM	PULP & PAPER	MINING	METAL CASTING	MUNICIPAL WPCPs
ARSENIC										
	10 x PWQO or 20 x GLWQA	1000						++		
	100 x PWQO or 200 x GLWQA	10000								
	1000 x PWQO or 2000 x GLWQA	100000								
	10000 x PWQO or 20000 x GLWQA	1000000								
1,4-DICHLOROBENZENE										
	10 x PWQO	40								
	100 x PWQO	400								
	1000 x PWQO	4000								
	10000 x PWQO	40000								
HEXACHLOROBENZENE										
	10 x PWQO	0.065	+		++					
	100 x PWQO	0.65			++					
	1000 x PWQO	6.5			+					
	10000 x PWQO	65								
alpha-BHC										
	10 x NYSDEC	0.1								
	100 x NYSDEC	1								
	1000 x NYSDEC	10								
	10000 x NYSDEC	100								
LINDANE (gamma-BHC)										
	10 x PWQO	0.1								
	100 x PWQO	1								
	1000 x PWQO	10								
	10000 x PWQO	100								
MERCURY										

LEGEND:
+ = 1 - 4% of samples exceeded specified criteria
++ = 5 - 24% of samples exceeded specified criteria
+++ = >25% of samples exceeded specified criteria
Information supplied by MISA Data Management and Municipal Sections

TABLE 2.3 SUMMARY OF MISA EFFLUENT DISCHARGE DATA AND FREQUENCY OF EXCEEDANCES OF VARIOUS HAZARD ASSESSMENT END-POINTS

ANALYTICAL PARAMETER	ASSESSMENT END-POINT	CONCENTRATION (ug/L)	OCM	IRON & STEEL	INORGANIC	PETROLEUM	PULP & PAPER	MINING	METAL CASTING	MUNICIPAL WPCPs
	10 x PWQO	2	+++		+++			+++	++	
	100 x PWQO	20	+		++			+++		
	1000 x PWQO	200			+			++		
	10000 x PWQO	2000								
PENTACHLOROPHENOL										
	10 x PWQO	5								
	100 x PWQO	50								
	1000 x PWQO	500								
	10000 x PWQO	5000								
PCB (TOTAL)										
	100 x PWQO	0.1	+		++					
	1000 x PWQO	1			+					
	10000 x PWQO	10								
PCDD-F/ 2,3,7,8-TCDD										
	10000 x PWQG	0.0002					++			
PCDD-F/ TOTAL TCDD										
	10000 x PWQG	0.0002	+		+		+++			
PCDD-F/ TOTAL TCDF										
	100 x PWQG	0.00002	++		++	+++	++			
	1000 x PWQG	0.0002			++	+++	++			
	10000 x PWQG	0.002			+					
PAH/ BENZO[A]PYRENE										
	100 x GLWQA	1		++						
	1000 x GLWQA	10								
	10000 x GLWQA	100								

LEGEND:
+ = 1 - 4% of samples exceeded specified criteria
++ = 5 - 24% of samples exceeded specified criteria
+++ = >25% of samples exceeded specified criteria
Information supplied by MISA Data Management and Municipal Sections

concentration found was 5 µg/L. At this upper level, HCB in water is not consideredto be highly toxic to aquatic biota during acute or chronic water-borne exposures (U.S. EPA, 1988; OMOE, 1984).

4.1.6 Mercury

Mercury is ubiquitous in industrial and municipal sector effluents. The OCM, pulp and paper, and metal casting sectors exhibited effluent concentrations of 2 µg/L or more and the mining and inorganic sectors exhibited effluent concentrations above 200 µg/L (Table 2.3). Concentrations of mercury in water at or above 2 µg/L (i.e., 10 times the PWQO) are highly toxic to aquatic life during short-term and long-term water-borne exposures (Eisler, 1987).

4.1.7 Pentachlorophenol (PCP)

Pentachlorophenol concentrations of less than 10 times the PWQO were detected in the pulp and paper sector (Table 2.3). The highest concentration found was approximately 3 µg/L. At this upper level, PCP is highly toxic to aquatic biota based on chronic toxicity data for water-borne exposures (Eisler, 1989; OMOE, 1984a).

4.1.8 Polychlorinated biphenyl (PCB)

PCB concentrations in effluents from the organic chemicals manufacturing, metal casting, and municipal sectors did not exceed 0.2 µg/l. However, concentrations of PCBs in some discharges from the inorganic chemicals sector exceeded the Provincial Water Quality Objective of 0.001 µg/L by 1000 times or more in a small percentage of samples (Table 2.3). At 1 µg/L, industrial waste streams are considered to be highly toxic to aquatic biota based on acute and chronic PCB toxicity data for water-borne exposures (Eisler, 1986; OMOE, 1979; Birge *et al.*, 1978).

4.1.9 Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD-Fs)

Polychlorinated dibenzo-p-dioxins or polychlorinated dibenzofurans were detected in effluents from the organic, inorganic, and pulp and paper sectors at levels greater than 10,000 times the PWQGs for 2,3,7,8-tetrachlorodibenzo-p-dioxin and 2,3,7,8-tetrachlorodibenzofuran (Table 2.3). At these levels, industrial effluents are considered to be highly toxic to aquatic life based on acute and chronic toxicity data for 2,3,7,8-TCDD and chronic toxicity data for 2,3,7,8-TCDF (Mehrle *et al.*, 1988; Eisler, 1986a).

A hazard evaluation of other dioxins or furans found in effluents from the OCM, iron and steel, inorganic, pulp and paper, and petroleum sectors was not undertaken because of limited available water quality criteria and toxicity information.

4.1.10 Polycyclic aromatic hydrocarbon (PAHs)

Benzo[*a*]pyrene concentrations in industrial effluent were found to exceed 1 µg/L in the iron and steel sector (Table 2.3). Moreover, waste streams containing 1 µg/L of benzo[*a*]pyrene are considered to be highly toxic to aquatic life based on acute and chronic toxicity data (Oris and Giesy, 1987; Newsted and Giesy, 1987; Hose *et al.*, 1984; Hannah *et al.*, 1982).

Since water quality criteria were not available for anthracene, benz[*a*]anthracene, benzo[*g,h,i*]perylene, perylene, and phenanthrene, a complete hazard evaluation of these PAH compounds found in effluents from the iron and steel, pulp and paper, metal casting, or the inorganic sectors was not undertaken. However, concentrations of these compounds in discharged effluents are not believed to be highly toxic to aquatic biota based on available monitoring information.

4.2 Summary of Hazard Evaluation

The environmental risk characterization of MISA industrial and municipal effluents clearly augmented the hazard identification and loadings information presented earlier in this report. Some sectors are discharging highly hazardous substances, such as arsenic (mining sector), mercury (organic chemical manufacturing, inorganic chemicals, mining, metal casting, and pulp and paper sectors), polychlorinated biphenyls (OCM and inorganic chemicals sectors), polychlorinated dibenzo-p-dioxins (OCM, inorganic, and pulp and paper sectors), and benzo[*a*]pyrene (iron and steel sector), at high concentrations that can exert toxic effects on aquatic organisms exposed directly to contaminated water for short periods of time (e.g., less than 96 hours).

Certain sectors are also discharging pentachlorophenol (pulp and paper sector) and polychlorinated dibenzofurans (organic, inorganic, and pulp and paper sectors) at low concentrations that can exert toxic effects on organisms in the immediate vicinity of point source discharges under chronic conditions.

Discharges of hexachlorobenzene (inorganic sector), mercury (inorganic and mining sectors), PCB (inorganic sector), and polychlorinated dibenzo-p-dioxins or dibenzofurans (organic, inorganic, petroleum, and pulp and paper sectors) at times exceeded concentrations corresponding to 1000 times the Provincial Water Quality Objectives or GLWQA specific objectives (Table 2.3). These results indicate an increased risk or likelihood for impairments of the aquatic environment, particularly in the vicinity of point source discharges.

5 Use Impairments / Receiving Water Impacts

The toxics problem in the Ontario Great Lakes watershed can be characterized using a chemical-specific approach to identify impairments or losses of beneficial uses of aquatic resources. This approach is considered most useful and practical for identifying impacts of hazardous substances and determining appropriate remedial

actions in the context of existing law and regulation. Furthermore, the Ministry of the Environment does not permit the bioconcentration of toxic substances in receiving waters (OMOE, 1984b).

In order to identify impairments of beneficial uses in the Ontario Great Lakes ecosystem, all available environmental quality data were compared to existing objectives, guidelines, or criteria (Table 2.4). The beneficial use impairments considered were: restrictions on fish and wildlife consumption; restrictions on dredging activities; restrictions on drinking water consumption; and impairments or degradation of water and sediment quality to levels affecting aquatic life.

The environmental data sets reviewed in this project included the Remedial Action Plan (RAP) stage 1 reports for 17 Areas of Concern located in Ontario (Figure 2.1), and all available monitoring studies conducted by the Ontario Ministry of the Environment, Environment Canada, and other agencies or research groups. Some of the important Ministry programs contributing information to this project included the Sports Fish Monitoring Program, the Spottail Shiner Biomonitoring Program, the Great Lakes Surveillance Program, the Provincial Water Quality Monitoring Network (e.g., Figures 2.2 and 2.3), the In-Place Pollutants Program, the Drinking Water Surveillance Program (Figure 2.4) and other studies or monitoring programs concerned with contaminants in effluents, ambient water, sediments, suspended sediments, and biota. A listing of the information sources reviewed is found in Appendix 'D'.

The assessment of use impairments in the Great Lakes basin encompasses a comprehensive ecosystem approach for defining environmental health in terms of viability and sustainability. The criteria selected for defining impairments take into account important socio-economic and ecosystem-level attributes necessary for maintenance of the system's health.

This approach integrates the complex interrelationships among terrestrial and aquatic ecosystems because air, land, or water releases of highly bioaccumulative and persistent compounds ultimately accumulate or bioconcentrate in aquatic ecosystems. Aquatic ecosystems are sensitive to inputs of highly hazardous substances and to changes to the integrity of the biosphere. Furthermore, the majority of Ontario's people and industries are located in the Great Lakes basin and depend on aquatic resources for food, water, recreation, transportation, and the self-renewing capabilities of natural systems.

The evaluation of receiving water impacts is summarized in the following section and in Table 2.5. A detailed discussion on which these comments are based is presented in Appendix 'C'.

TABLE 2.4 AMBIENT WATER, DRINKING WATER, SEDIMENT AND BIOTA CRITERIA USED FOR COMPARISONS

PARAMETER	PWQO/G (ng/L)	ODWO (ng/L)	DREDGED MATERIAL GUIDELINES (mg/kg)	DRAFT SEDIMENT Q. G.		BIOTA CRITERIA		
				LOWEST EFFECT LEVEL (mg/kg)	SEVERE EFFECT LEVEL (mg/kg)	NYSDEC (mg/kg)	* IJC (mg/kg)	HWC (mg/kg)
ARSENIC	100000	25000	8	6	33			
DDT & METABOLITES	3	30000		0.007***	12***		1	
1,4-DICHLOROBENZENE	4000	1000						
DIELDRIN	1	700		0.002	91		0.3	
HEXACHLOROBENZENE	6.5	10 (WHO)a		0.02	** 24	0.33		
ALPHA-HEXACHLOROCYCLOHEXANE	10(NYSDEC)			0.006	**10	0.1		
GAMMA-HEXACHLOROCYCLOHEXANE (LINDANE)	10	4000		0.003	**1	0.1	0.3	
MERCURY	200	1000	0.3	0.2	2		0.5	0.5
MIREX	1			0.007	130		<D.L.	
PENTACHLOROPHENOL	500	30000				2		
PCB (total)	1	3000	0.05	0.07	** 530	0.11	0.1	2
2,3,7,8 TCDD (or TOTAL TCDD)	0.00002	15 pg/L				3 pg/g		0.00002
2,3,7,8 TCDF (or TOTAL TCDF)	0.0002	15 pg/L						
BENZO[A]PYRENE	10 (IJC)	10		1.0 (IJC)			1	
PAH (TOTAL)				2	** 11000			
TOXAPHENE	8	5000						

* GLWQA Specific Objective

** These values to be normalized to the actual TOC measured in sediment

*** For total DDT (see other values for DDE, DDD, etc.)

a World Health Organization guideline

FIGURE 2./ AREAS OF CONCERN IN THE GREAT LAKES BASIN

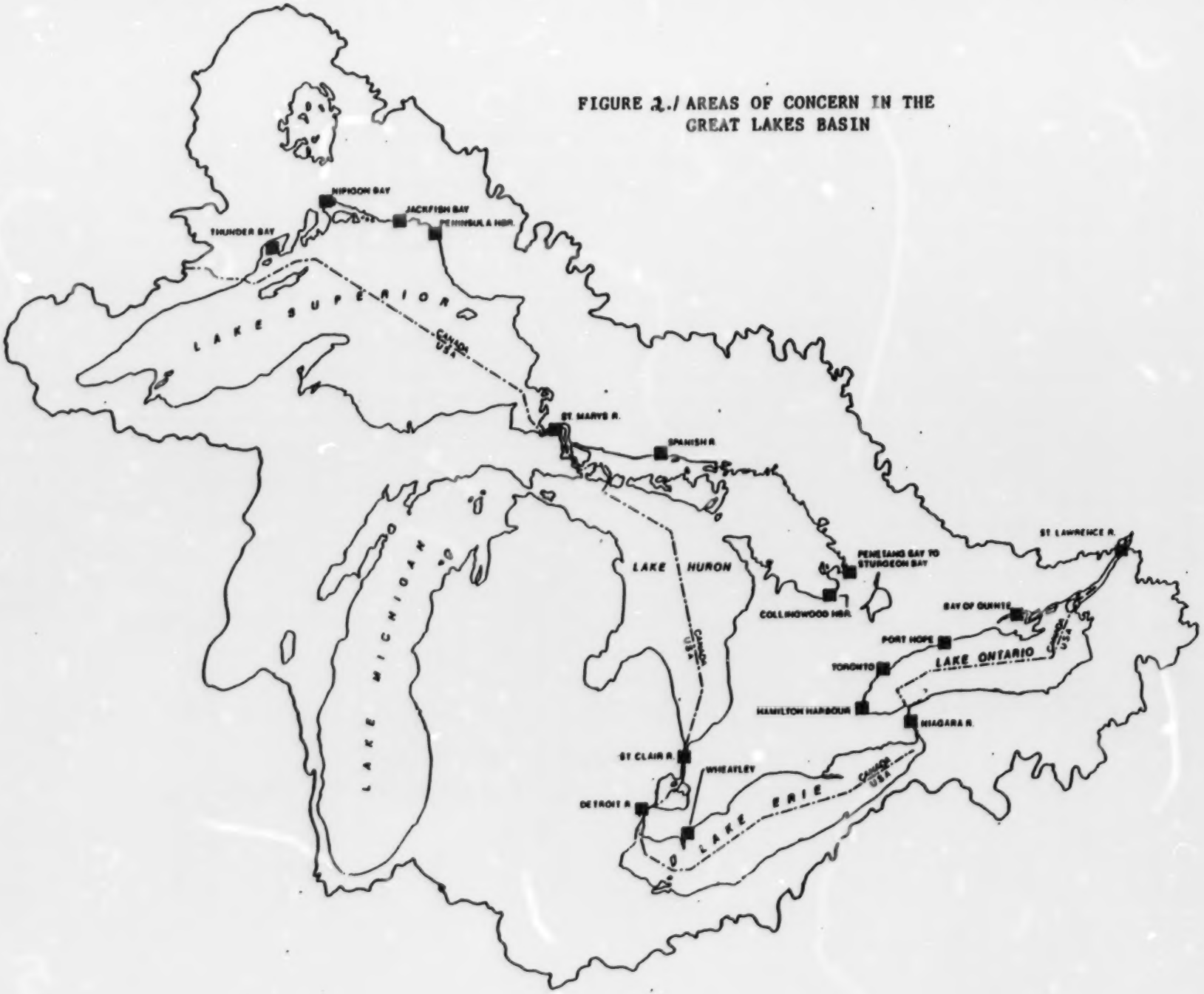

Figure 2.2

Arsenic Sampling Sites

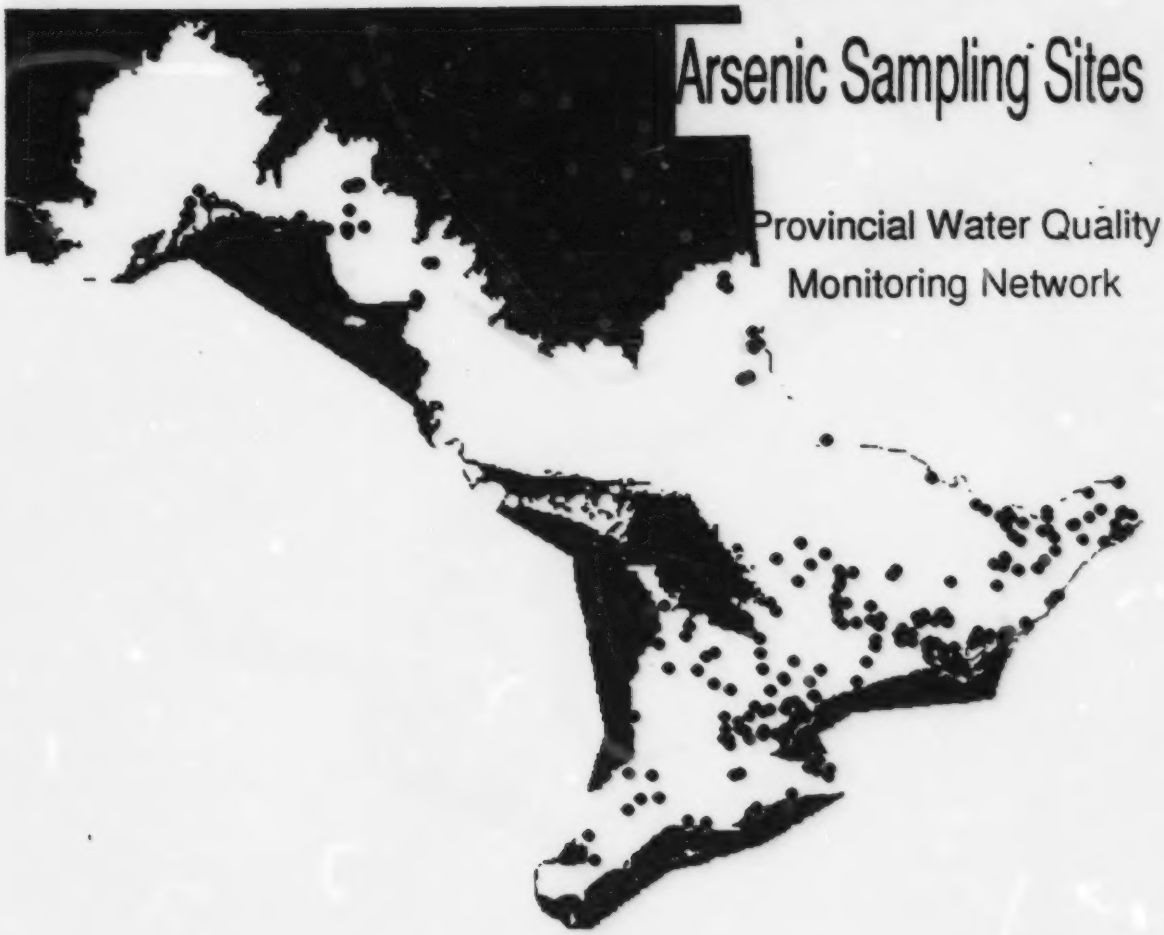

Figure 2.3

PCB and HCB Sampling Sites

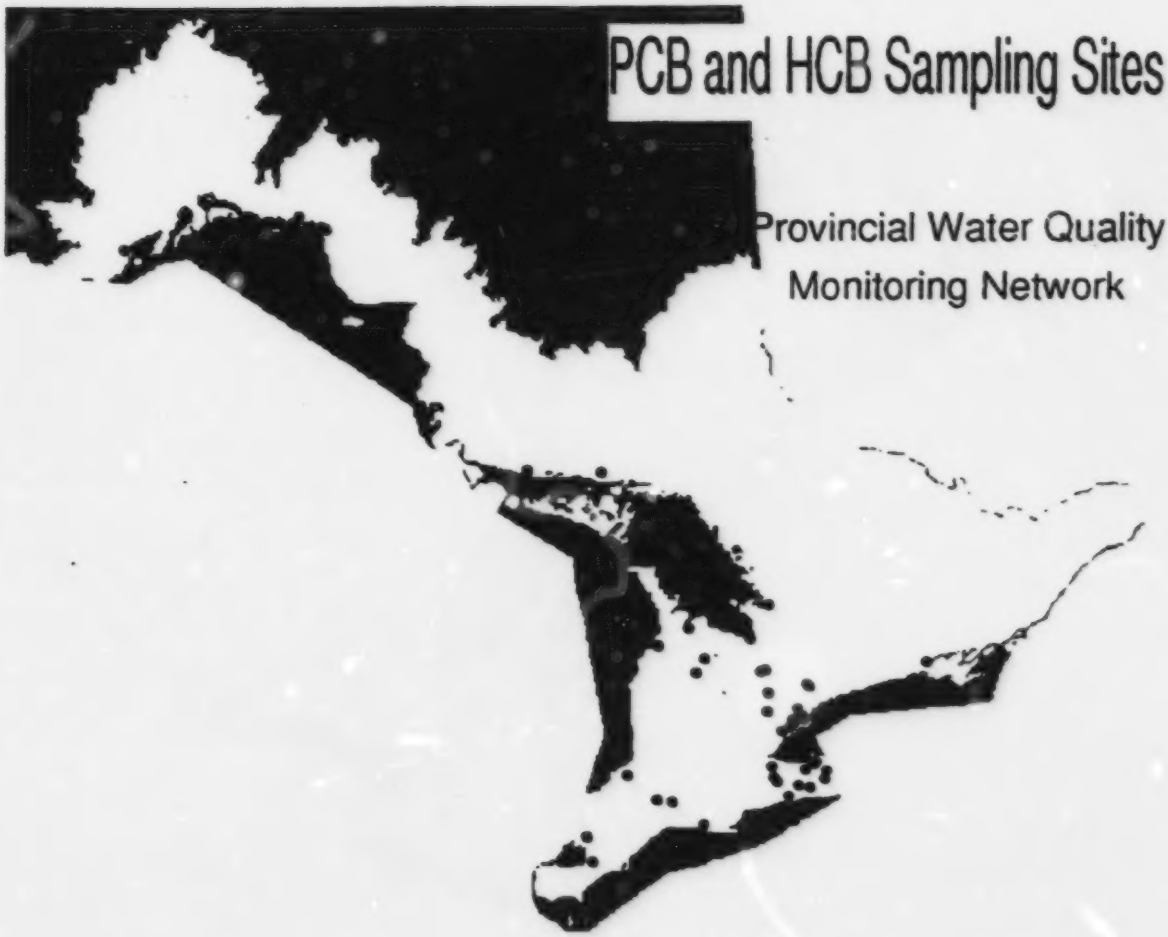

Figure 2.4

Drinking Water Surveillance Program

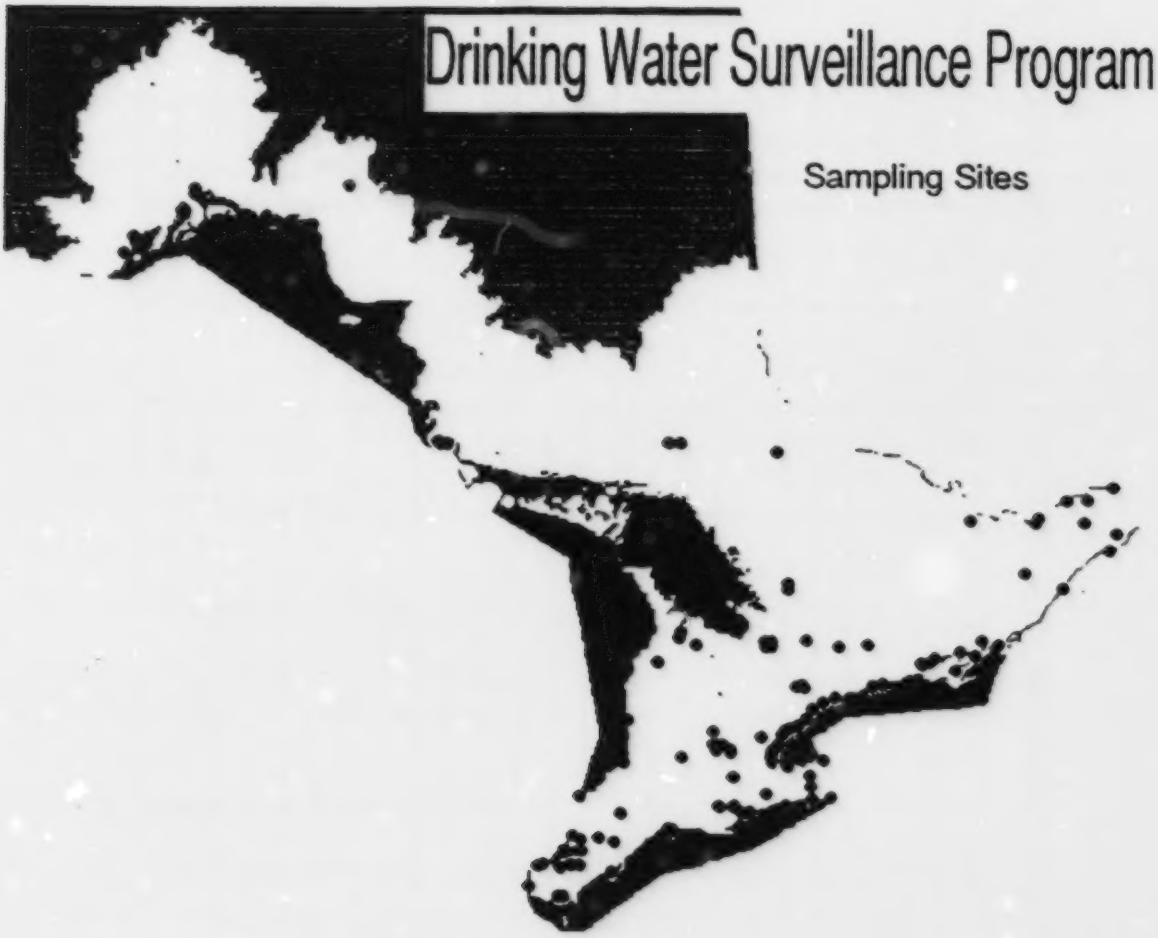

TABLE 2.5 USE IMPAIRMENTS* IDENTIFIED IN THE ONTARIO GREAT LAKES BASIN

PARAMETER	Lake Superior	St. Marys River System	Lake Huron	St. Clair/Detroit River System	Lake Erie	Niagara River	Lake Ontario	St. Lawrence River	Inland Lakes & Rivers
arsenic	S	S	S	S	S	S	S	S	W S
DDT & metabolites	W S	S	S	W S	S	S	W S	S	W S
1,4-dichlorobenzene									
3,3'-dichlorobenzidene									
Dieldrin	S	S	S	S		S	W S	S	
hexachlorobenzene	W S		S	W S		S	W S	S	
alpha-hexachlorocyclohexane	W			S			S		
gamma-hexachlorocyclohexane			S	W S			W		W S
mercury	W S B	W S B	S B	W S B	W S B	S B	W S B	S B	S B
Mirex						S B	S B	B	
pentachlorophenol							W		W
Dioxins & Furans	B					B	B		
PCB (total)	W S B	S	W S B	W S B	W S B	W S B	W S B	W S B	W S B
PAH/ anthracene	S	S		S			S	S	
PAH/ benzo[g,h,i]perylene		S					S		S
PAH/ benzo[a]pyrene	S	S		S		S	S	S	S
PAH/ benz[a]anthracene	S	S		S			S	S	S
PAH/ perylene		S							
PAH/ phenanthrene		S		S			S	S	S
Toxaphene									
tributyltin									

LEGEND: W = water; S = sediment; B = biota

* = Defined as an exceedance of a water quality criterion, sediment quality criterion, or sport fish or other biota criterion.

5.1 Arsenic

Receiving water impacts, such as impaired water or sediment quality and restrictions on dredging activities, exist in several Areas of Concern and rivers throughout the Great Lakes ecosystem. Exceedances of the Ontario Sediment Quality Guidelines (severe effect level and lowest effect level) and PWQO indicate a widespread concern for aquatic toxicity and loss of fish or invertebrate habitat. Furthermore, some mining operations in Ontario exceed the Ministry's guidelines or requirements for safely discharging arsenic.

5.2 DDT and metabolites (DDE, DDD)

DDT or its degradation products have caused impairments of water and sediment quality in many areas of Ontario. Moreover, exceedances of the PWQO and Sediment Quality Guidelines (lowest and severe effect levels) indicate a widespread concern for aquatic toxicity and loss of fish or invertebrate habitat.

5.3 1,4-Dichlorobenzene (1,4-DCB)

Although beneficial use impairments based on available criteria have not been reported in the aquatic environment, elevated concentrations of 1,4-DCB are found in open waters throughout the Great Lakes ecosystem. However, concentrations are generally less than 5 ng/L or well below the PWQO. Also, elevated levels in biota and sediments have been found in areas receiving industrial inputs.

5.4 3,3'-Dichlorobenzidine

Receiving water impacts of 3,3'-dichlorobenzidine have not been reported in the Ontario Great Lakes basin.

5.5 Dieldrin

Concentrations of dieldrin have exceeded the PWQO of 1 ng/L for the protection of aquatic life in nearshore areas of Lake Ontario such as Port Weller Harbour and Toronto Harbour. Concentrations of dieldrin adsorbed to bottom sediments have exceeded the Ontario Sediment Quality Guideline (lowest effect level) in Areas of Concern such as Peninsula Harbour, St. Marys River, Penetang Harbour, Collingwood Harbour, St. Clair River, Niagara River, Hamilton Harbour, Toronto Harbour, Bay of Quinte, and the St. Lawrence River.

5.6 Hexachlorobenzene (HCB)

Receiving water impacts, such as impaired sediment and water quality conditions and elevated concentrations of HCB in invertebrates, caged mussels, fish, waterfowl and snapping turtle eggs, have been found in areas receiving industrial inputs. There is increased risk for aquatic toxicity and loss of fish and invertebrate habitat in the St. Clair River and the St. Lawrence River based on exceedances of the Ontario Sediment Quality Guidelines (SQG) (severe effect level and lowest effect level) and the Provincial Water Quality Objective. In addition, exceedances of the SQG (lowest effect level) have been found in the Niagara River, Detroit River, Peninsula Harbour, Collingwood Harbour, and the Bay of Quinte.

5.7 Alpha-Hexachlorocyclohexane

The alpha isomer (also known as alpha-BHC or alpha-HCH) is ubiquitous in the Great Lakes ecosystem. Elevated concentrations have been found in water, sediments, and biota. Exceedance of the NYSDEC (New York State Department of Environmental Conservation) ambient water quality criterion of 10 ng/l for the protection of aquatic life was found in Peninsula Harbour. Sediment conditions considered harmful to aquatic life were found in the St. Clair River and Hamilton Harbour.

5.8 Gamma-Hexachlorocyclohexane

This substance (also known as gamma-BHC, gamma-HCH or Lindane) has been detected in water, sediment or biota samples from several Areas of Concern and tributaries throughout the Great Lakes basin. Impairments or degradation of ambient water quality for supporting aquatic life were found at 13 of 66 river and stream monitoring sites and in Hamilton Harbour and Toronto Harbour. In addition, impairments of sediment quality to levels considered harmful to aquatic life were found in Collingwood Harbour, the St. Clair River, Canagagigue Creek, and Rice Lake.

5.9 Mercury

Mercury has caused beneficial use impairments throughout the Great Lakes ecosystem. These impairments include restrictions on fish consumption by humans and wildlife, restrictions on dredging activities, and impairments of water and sediment quality based on exceedances of available criteria. Exceedances of the GLWQA specific objective for biota of 0.5 mg/kg indicate a widespread concern for behavioural effects in fish-consuming birds.

5.10 Mirex

Mirex is the contaminant mainly responsible for restrictions on human consumption of Lake Ontario sport fish. Although significant declines have occurred in recent years, mirex concentrations in fish from some locations in the western end of the lake, such as the Credit River, continue to be elevated. Also, mirex levels in fish from the St. Lawrence River near Cornwall exceeded the Health and Welfare Canada guideline of 0.1 mg/kg and resulted in consumption advisories for protecting human health.

Mirex was detected in forage fish from some Niagara River, Lake Ontario and St. Lawrence River collection sites and, therefore, exceeded the GLWQA specific objective of 'non-detectable' for protecting birds and animals that consume fish.

Exceedances of the Ontario Sediment Quality Guideline (SQG) (lowest effect level) in the Niagara River, Lake Ontario, and the St. Lawrence River indicate toxic conditions and a loss of fish and invertebrate habitat.

5.11 Pentachlorophenol (PCP)

Pentachlorophenol has been detected in water, sediment, and biota in Areas of Concern such as Thunder Bay, Toronto Harbour, Bay of Quinte, and the St. Lawrence River. Water concentrations have occasionally exceeded the Provincial Water Quality Objective of 500 ng/L. These exceedances tend to be localized in the vicinity of continuous inputs, predominantly from wood preserving plants and to a lesser extent from pulp and paper mills.

5.12 Polychlorinated Biphenyls (PCBs)

PCBs, like mercury, have caused beneficial use impairments such as restrictions on fish consumption by humans and wildlife, restrictions on dredging activities, and impairments of sediment and ambient water quality throughout the Great Lakes watershed.

The exceedances of the Ontario Sediment Quality Guideline (lowest effect level), the GLWQA specific objective for whole fish, and the New York State Department of Environmental Conservation biota criterion in Areas of Concern indicate a widespread potential for aquatic toxicity and reproductive toxicity or cancer in birds and mammals that consume contaminated fish. However, actual occurrence of effects depends on the extent and duration to which animals consume fish with residues in excess of 0.1 mg/kg.

5.13 Polychlorinated Dibenzo-p-dioxins and Dibenzofurans (PCDD-Fs)

Restrictions on the consumption of sport fish, based on levels of 2,3,7,8-TCDD (or toxic equivalents), exist in the Niagara River, Lake Ontario, and Lake Superior.

Furthermore, elevated levels of dioxins and furans in water, sediment, caged mussels, forage fish, sport fish, herring gull eggs and snapping turtle eggs have been detected in areas receiving industrial inputs. These results suggest an increased risk of reproductive effects or cancer in wildlife that consume contaminated fish.

5.14 Polycyclic Aromatic Hydrocarbons (PAHs)

Elevated concentrations of PAH compounds, particularly benzo[*a*]pyrene, phenanthrene, benz[*a*]anthracene, anthracene, perylene, and benzo[*g,h,i*]perylene, have been detected in water, sediment, aquatic invertebrates, caged mussels, fish, or waterfowl eggs in Areas of Concern such as the St. Mary's River, St. Clair River, Detroit River, Niagara River, Hamilton Harbour, Bay of Quinte, and the St. Lawrence River. Moreover, sediment concentrations of each of these compounds exceeded the Ontario SQG (lowest effect level) for total PAH compounds. This indicates an increased risk for aquatic toxicity and loss of fish and invertebrate habitat. Also, exceedances of the International Joint Commission sediment quality objective of 1 mg/kg for benzo[*a*]pyrene in Thunder Bay Harbour, the St. Mary's River, Niagara River, and Hamilton Harbour indicate a widespread concern for tumour induction in fish.

5.15 Toxaphene

Although beneficial use impairments based on available criteria have not been reported, concentrations of less than 2 ng/L or below the PWQO are found in open waters throughout the Great Lakes ecosystem. Toxaphene has also been detected in Ontario sport fish at levels below 3 mg/kg. Presently, there are no restrictions on human consumption of sport fish because of toxaphene levels.

5.16 Tributytin

There is limited information available to assess beneficial use impairments caused by tributyltin. However, based on findings from the Severn Sound Area of Concern, Whitby Harbour, and Oshawa Harbour, elevated concentrations in water, sediments, or biota may occur near marinas from releases of tributyltin oxide used as an active ingredient in antifoulant paints applied to boat hulls. Also, inputs from industrial activities may cause elevated concentrations particularly in the St. Clair and Detroit Rivers.

6 Summary of Ontario-Specific Data Evaluation

The Primary List was screened against a variety of Ontario-specific supporting information concerning:

- presence and loadings from industrial and municipal point sources discharging directly into Ontario surface waters;
- toxicity and potential hazards of MISA industrial and municipal effluents; and
- Ontario receiving water impacts.

In general, these evaluations support the position that the Primary List substances should be retained on a short list of candidate substances for bans or phase-outs from industrial and municipal point sources. The basis for this position is summarized below.

6.1 Point Source Loadings

The available loadings information indicate there are significant industrial or municipal point source inputs of fifteen highly hazardous substances to the aquatic environment, particularly arsenic, 1,4-dichlorobenzene, hexachlorobenzene, lindane, mercury, pentachlorophenol, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons. Direct industrial discharges of polychlorinated dibenzo-p-dioxins or dibenzofurans and municipal discharges of alpha-BHC were not greater than 1 kg per year.

6.2 Environmental Hazards of Point Source Discharges

Several highly hazardous substances are being discharged at high concentrations considered to be acutely toxic to aquatic organisms. These include arsenic, mercury, PCBs, polychlorinated dibenzo-p-dioxins and benzo[*a*]pyrene. Furthermore, some industrial sectors are discharging pentachlorophenol and polychlorinated dibenzofurans at low concentrations considered to be toxic to aquatic organisms when exposed to contaminated water for a major part of their lifespan.

Discharges of hexachlorobenzene, mercury, PCBs and polychlorinated dibenzo-p-dioxins or -furans at times exceeded concentrations corresponding to 1000 times the Provincial Water Quality Objectives or GLWQA specific objectives. These findings indicate an increased risk of serious environmental impacts including sediment accumulation and bioconcentration of persistent toxic substances, impaired fish habitat, loss of beneficial uses of aquatic resources, and increased costs for remediation in the vicinity of point source discharges.

6.3 Receiving Water Impacts

Receiving water impacts in Ontario were found for all Primary List substances except 3,3'-dichlorobenzidine (for which no data were available). These included elevated concentrations (i.e. above background levels) found in water, sediment, or biota in areas receiving anthropogenic inputs. Furthermore, widespread use impairments based on exceedances of available criteria were identified for all Primary List substances except 1,4-dichlorobenzene, 3,3'-dichlorobenzidine, toxaphene, and tributyltin. 1,4-dichlorobenzene was not detected at levels exceeding established criteria, and use impairments could not be ascertained for 3,3'-dichlorobenzidine and tributyltin as there are no water, sediment or biota criteria for these substances.

Impairments of water quality for supporting aquatic life were found for DDT and metabolites, dieldrin, HCB, alpha-BHC, gamma-BHC, mercury, PCP, and PCBs. Impairments of sediment quality for supporting aquatic life were found for arsenic, DDT and metabolites, dieldrin, HCB, alpha-BHC, gamma-BHC, mercury, mirex, anthracene, benz[*a*]anthracene, benzo[*a*]pyrene, benzo[*g,h,i*]perylene, perylene, and phenanthrene. Restrictions on dredging activities were found for arsenic, mercury, and PCBs. Restrictions or limitations on the safe consumption of fish by humans and wildlife were found for mercury, mirex, PCBs, and 2,3,7,8-TCDD. However, no restrictions on drinking water supplies for human consumption were found or attributable to the Primary List substances.

Conclusions

- Of approximately 800 substances and groups of substances assessed, 21 have been designated as being most inherently hazardous due to their persistence, bioaccumulation potential and toxicity. These substances appear on the Primary List of Candidate Substances for Bans or Phase-Outs.

- It has been demonstrated that seventeen of the Primary List substances have caused impairments of beneficial uses of water, sediment or biota in Ontario. Of the remaining four substances, 1,4-dichlorobenzene and toxaphene have not been detected at levels which exceed established criteria, and 3,3'-dichlorobenzidine and tributyl tin could not be evaluated from a receiving water/sediment/biota impaired use perspective because no appropriate criteria have been established for these substances.

- Nineteen of the 21 Primary List substances were monitored under MISA or in the 1987 Municipal Water Pollution Control Plants Study. Analysis of the monitoring data has demonstrated that 13 substances are being directly discharged to surface water by Ontario-based industrial point sources and that 4 substances are being directly discharged by Ontario municipal water pollution control plants. Overall, 15 Primary List substances are being discharged by Ontario-based point sources; the substances not found to be discharged are DDT/DDD/DDE, dieldrin, mirex and toxaphene. Monitoring data were not available for tributyl tin and 3,3'-dichlorobenzidine.

- Several Primary List substances were found to be discharged at levels considered to be acutely toxic to aquatic biota. These were arsenic, mercury, PCBs, 2,3,7,8-TCDD and benzo[*a*]pyrene.

- An additional 46 substances were designated as being toxic and either persistent or bioaccumulative, or as being both persistent and bioaccumulative but somewhat less toxic than those on the Primary List. These substances appear on the Secondary List of Candidate Substances for Bans or Phase-Outs. This list is recommended as a "second tier" of substances, to be considered after those on the Primary List have been addressed.

Appendix 'A'

Rationale for Listing Substances

Part I: Substances on the Primary
Candidate Substances List for Bans or Phase-Outs

Part II: "Group A" Substances
on the Secondary List

Part III: "Group B" Substances
on the Secondary List

Part IV: "Group C" Substances
on the Secondary List

Key to Symbols:

* - Indicates the study on which the final score was based

Q - The data did not precisely match the criteria, or the method was unusual

W - The score was assigned on a worst-case basis

E - The score was estimated using a model or through structural analogy to a similar substance

L - The data set was limited

Part I: Substances on the Primary List

Anthracene **120-12-7**

Persistence:

Soil:

Score: 7

Basis: $T_{\frac{1}{2}}$ = 50 days to 1.26 years based upon aerobic soil die-away test data (SRC,1989)

Water:

Score: 0E

Basis:* $T_{\frac{1}{2}}$ = 0.58 to 1.7 hours based upon photolysis half life in water (SRC,1989)

* $T_{\frac{1}{2}}$ for photooxidation of dissolved anthracene under natural sunlight conditions = 0.6 hours (Smith et al.,1978, Southworth, 1979a)
* 52.9% and 32.6% remained after 5 and 10 hours respectively when exposed to natural light in a mixed acetone-water or carbon tetrachloride-water solution (Nagata et al., 1977; Neff, 1985)
* Half life for photolysis in a 5 metre deep inland water body without partioning to sediment = 4.5 days; with partitioning to sediment $T_{\frac{1}{2}}$ = 5.2 days (Zepp et al., 1979)

Sediment:

Score: 10Q

Basis:* $T_{\frac{1}{2}}$ = 16.5 weeks (CMR,1981)

Air:

Score: 0E

Basis:* $T_{\frac{1}{2}}$ = 0.58 to 1.7 hours based upon photolysis half life in water (SRC,1989)

Bioaccumulation:

Score: 7

Basis:* BCF Bluegill: 900 (CESARS,1989)
BCF Fathead Minnow: 480 (CESARS,1989)
* BCF Golden Orfe: 910 (Freitag et al.,1982)
Log BCF Daphnia magna (24h): 2.9868 (970) (Newsted et al., 1987)

Anthracene **120-12-7**

Toxicity:

Acute Aquatic:
Score: 10Q

Basis: Score based on aquatic toxicity to fish and aquatic invertebrates. Q tag assigned because of presence of non-conventional data. "UV"-LT50 indicates the test included the use of artificial UVA or UVB light sources. Although these tests are not conventional in this respect, they may more closely represent the environmental situation where a number of PAHs, including anthracene, are UV light-activated (at ecologically relevant light intensities) to highly toxic compounds.(Source:MOE, 1990.The Environmental Toxicology of Polycyclic Aromatic Hydrocarbons).

Bluegill: 96h UV-LT50: 100 uW/cm^2 UVA: 0.005-0.046 mg/l
Bluegill: 96h UV-LT50: UVB: 14.8, 70, 170 uW/cm^2: 0.26, 0.18, 0.12 mg/l
Bluegill: 9h LC100: sunlight: 0.013 mg/l
Fathead minnow: UV-LT50: 15.75h: 0.005 mg/l
Daphnia sp.: UV-LT50: 4.98h: 0.015 mg/l
Daphnia: UV-1h LC50: 0.02 mg/l
Mosquito larvae: UV-1h LC50: 0.15 mg/l

Arsenic 7440-38-2

Persistence:

Soil:
Score: 10

Basis: Arsenic is an element

Water:
Score: 10

Basis: Arsenic is an element

Sediment:
Score: 10

Basis: Arsenic is an element

Air:
Score: 10

Basis: Arsenic is an element

Bioaccumulation:
Score: 7Q

Basis:* BCF Fish: 700 (CMR,1978)
* BCF Molluscs 650 (CMR,1978)

Toxicity:

Carcinogenicity:
Score: CMR 7

Basis: The major concern regarding arsenic compounds appears to be their mutagenic and carcinogenic potential. Arsenic compounds have been found to be weak or inactive in causing gene mutation however are capable of causing chromosomal aberrations in vitro. In vivo chromosome studies and DNA repair/damage studies have provided equivocal evidence. IARC (listed GRP 1) has determined that inadequate evidence for the carcinogenicity of arsenic compounds in animals exists however sufficient epidemiological evidence exists indicating that these compounds are skin and lung carcinogens in humans. Arsenic appears on the CEPA Priority Toxic Substances list.

Benz(a)anthracene **56-55-3**

Persistence:

Soil:

Score: 10L

Basis:* $T_{\frac{1}{2}}$ = 102 days to 1.86 years based upon aerobic soil die-away test at 10-30°C (SRC,1989)

Water:

Score: 0

Basis:* $T_{\frac{1}{2}}$ = 1 to 3 hours based upon estimated photolytic half life in water (SRC,1989)

* $T_{\frac{1}{2}}$ = 1.6 days in air saturated water based upon free radical oxidation (Smith et al., 1977, 1978)
* $T_{\frac{1}{2}}$ < 5 hours in mixed acetone-water or carbon tetrachloride-water solutions (Nagata et al.,1977; Neff,1985)
* $T_{\frac{1}{2}}$ = 9.2 days for direct photolysis in a 5 metre deep inland water body with partitioning to sediment; $T_{\frac{1}{2}}$ = 3.7 days without partitioning (Zepp et al.,1979)

Sediment:

Score: 10E

Basis:* based on analogy to other PAHs it is assumed to have a similar biodegradation half life in sediment ($T_{\frac{1}{2}}$ > 7000 hours), for clean sediment 10 to 400 times longer (Prelim.,1987)

Air:

Score: 0E

Basis:* $T_{\frac{1}{2}}$ = 1 to 3 hours based upon estimated photolysis half life in water (SRC,1989)

Bioaccumulation:

Score: 7

Basis:* Log BCF Daphnia magna: 10225 (Newsted et al.,1987)

* Log BCF Fathead minnow: 4 (10000) (Ma et al.,1990)
* BCF Fathead minnow: 850 (Oris et al.,1987)

Log BCF Golden Ide: 2.54 (347) (Ma et al.,1990)
Log Kow: 5.35 (Ma et al.,1990)
Log Kow: 5.613 (Ma et al.,1990)
Log Kow: 5.91 (Ma et al.,1990)
Log Kow: 5.61 (Ma et al.,1990)

Benz(a)anthracene **56-55-3**

Toxicity:

Acute Aquatic:
Score: 10Q

Basis: Score based on acute toxicity to daphnia and Fathead minnows. Q tag assigned because of the presence of questionable data (see anthracene):

Daphnia sp.: UV-LT50: 12.51h: 0.002 mg/l
Daphnia sp.: 96h LC50: 0.01 mg/l
Fathead minnow: UV-LT50: 65.09h: 0.002 mg/l

Carcinogenicity:

IARC group 2A: sufficient evidence of carcinogenesis to animals, probable human carcinogen.

Benzo(a)pyrene **50-32-8**

Persistence:

Soil:

Score: 10L

Basis:* $T_{\frac{1}{2}}$ = 57 days to 1.45 years based upon aerobic soil die-away test (SRC,1989)

Water:

Score: 0E

Basis:* $T_{\frac{1}{2}}$ = 4.3 days for free radical oxidation in air saturated water (Smith et al., 1977,1978)

* $T_{\frac{1}{2}}$ = 0.5 hours for photooxidation under natural sunlight (Smith et al., 1978; Southworth, 1979a)
* $T_{\frac{1}{2}}$ for photolysis in a 5 meter deep inland water body with partitioning to sediment = 13 days; without partitioning $T_{\frac{1}{2}}$ = 3.2 days (Zepp et al., 1979)
* $T_{\frac{1}{2}}$ = 0.37 to 1.1 hours estimated based on photolysis in water (SRC,1989)

Sediment:

Score: 10E

Basis:* based on analogy to other PAHs it is assumed to have a similar biodegradation half life in sediment ($T_{\frac{1}{2}}$ > 7000 hours), for clean sediment 10 to 400 times longer (Prelim.,1987)

Air:

Score: 0E

Basis: * $T_{\frac{1}{2}}$ = 0.37 to 1.1 hours estimated based on photolysis in water (SRC,1989)

Benzo(a)pyrene

50-32-8

Bioaccumulation:
Score: 7

Basis: Log BCF Daphnia magna (24h): 4.1059 (12761)
(Newsted et al., 1987)
BCF Daphnia magna: 7943 (Ma et al.,1990)
BCF Daphnia magna: 2818 (Ma et al.,1990)
* BCF Bluegill: 2657 (Ma et al.,1990)
BCF Bluegill: 490 (Ma et al.,1990)
BCF Golden Orfe: 479 (Ma et al.,1990)
BCF Largemouth Bass: 12.6 (Ma et al.,1990)
Log Kow: 6.34 (Ma et al.,1990)
Log Kow: 5.60 (Ma et al.,1990)

Toxicity:

Acute Aquatic:
Score: 10Q

Basis: Score based on acute toxicity to Daphnia sp. and Fathead minnows. Q tag assigned because of some questionable data (see anthracene):

Daphnia sp.: 96h LC50: 0.005 mg/l
Daphnia sp.: UV-LT50: 4.44h: 0.002 mg/l
Fathead minnow: 7d posthatch: UV-LT50: 40.05h: 0.006 mg/l

Chronic Aquatic:
Score: CMR 7

Basis: Score based on MATC (growth) for Rainbow trout of <0.08 mg/l

Carcinogenicity:

IARC (listed Group 2A) has determined that there is sufficient evidence that benzo(a)pyrene is carcinogenic to experimental animals and that it is a probable human carcinogen.

Benzo(ghi)perylene **191-24-2**

Persistence:

Soil:
Score: 10

Basis:* $T_{\frac{1}{2}}$ = 590 to 650 days based upon aerobic soil die away test data at 10-30°C (SRC,1989)

Water:
Score: *

Basis:

Sediment:
Score: 10E

Basis:* based on analogy to other PAHs it is assumed to have a similar biodegradation half life in sediment ($T_{\frac{1}{2}}$ > 7000 hours), for clean sediment 10 to 400 times longer (Prelim.,1987)

Air:
Score: 0E

Basis:* $T_{\frac{1}{2}}$ = 0.321 to 3.21 hours based upon estimated photooxidation half life in air (SRC,1989)

Bioaccumulation:
Score: 7L

Basis:* Fathead minnow: 6816 (OMOE,1990f)
Daphnia magna: 28288 (OMOE,1990f)
Log Kow: 6.51 (Prelim.,1987)
Log Kow: 7.23 (Prelim.,1987)
Log Kow: 7.10 (Prelim.,1987)

Toxicity:

Acute Aquatic:
Score: 10Q

Basis: Score based on acute toxicity to Daphnia sp.. A Q tag was assigned due to presence of questionable data (see anthracene):

Daphnia sp.: UV-LT50: 13.82H: 0.0002 mg/l

DDD 72-54-8

Persistence:

Soil:

Score: 10Q

Basis: Under anaerobic conditions DDT is tranformed to DDD via reduction dechlorination, DDD is very resistant to further transformation (Prelim.,1991)
T 1/2 = 2 to 15.6 years based upon observed rates of biodegradation of DDT in aerobic soils under field conditions (SRC,1989)
T 1/2 = 70 days to 294 days based upon anaerobic flooded soil die-away study data for two soils (SRC,1989)

Water:

Score: 10

Basis: The hydrolysis half-life for DDD in water at pH 5 and 9 are 190 years and 570 days respectively (Prelim.,1991)
The estimated oxidation half-life in water is 22 years (Prelim.,1991)
No degradation occurred during an 8 week test using river water in a sealed jar (Prelim.,1991)
No losses occurred during 8 weeks using tests with distilled water (Prelim.,1991)
The estimated half-life for volatilization is a few days to several weeks (Prelim.,1991)

Sediment:

Score: 10Q

Basis: Sorption to sediment must be an important fate process based on inference from DDT (Prelim.,1991)
Under anaerobic conditions DDT is transformed to DDD via reduction dechlorination, DDD is very resistant to further transformation (Prelim.,1991)
T 1/2 = 70 days to 294 days based upon anaerobic flooded soil die-away study data for two soils (SRC,1989)

Air:

Score: 0E

Basis: T 1/2 = 13.3 hours to 5.54 days based upon estimated rate constant for reaction with hydroxyl radicals (SRC,1989)

Bioaccumulation:

Score: 7

Basis: BCF: Carp: 2710 (Prelim.,1991)
BCF: Fish: 6500 (Prelim.,1991)
BCF: Snail: 933 - 4460 (Prelim.,1991)
BCF: Mosquito larvae: 967 (Prelim.,1991)

Toxicity:

Acute Aquatic:

Score: 10

Basis: Score based on high acute aqautic toxicity of DDD to scud (*Gammarus* sp.) and freshwater fish (Prelim.,1991):

largemouth bass: 96h LC50: 0.042 mg/l
rainbow trout: 96h LC50: 0.070 mg/l
walleye: 96h LC50: 0.014 mg/l
Gammarus fasciatus: 96h LC50: 6.0 E-04 mg/l

DDE 72-55-9

Persistence:

Soil:

Score: 10Q

Basis: T 1/2 = 2 to 15.6 years based upon rates of biodegradation of DDT in aerobic soils under field conditions (SRC,1989)
T 1/2 = 16 to 100 days based upon anaerobic flooded soil die-away study data for DDT for two soil types (SRC,1989)

Water:

Score: 0

Basis: The volatilization half-lives for DDE in pure water, San Francisco bay, American River, and Sacramento River water are as follows: 0.67 hours, 1.2 hours, 1.4 hours, 1.9 hours respectively (Prelim.,1991)
The photolytic half-life of DDE in San Francisco bay water is 1.1 days (Prelim.,1991)
The half-life for photolysis of DDE in pure water under summer and winter sunlight conditions are 1 and 6 days respectively (Prelim.,1991)
T 1/2 = 15 hours to 6.1 days for direct photolysis of DDE in water (SRC,1989)

Sediment:

Score: 10

Basis: The biodegradation half-life for DDE in sediment is 1100 days (Prelim.,1991)
T 1/2 = 16 to 100 days based upon anaerobic flooded soil die-away study data for DDT for two soil types (SRC,1989)

Air:

Score: 0E

Basis: T 1/2 = 17.7 hours to 7.4 days based upon estimated photooxidation half-life in air (SRC,1989)

Bioaccumulation:

Score: 7

Basis: BCF: Carp: 8450 (Prelim.,1991)
BCF: Fathead minnow: 32d: 51000 (Prelim.,1991)
BCF: Mosquitofish: 33d: 12037 (Prelim.,1991)

Toxicity:

Acute Aquatic:

Score: 10

Basis: Score based on high acute toxicity of DDE to freshwater fish and copepods (Prelim., 1991):

atlantic salmon: 96h LC50: 0.096 mg/l
rainbow trout: 96h LC50: 0.032 mg/l
copepods: 96h LC50: 0.0025 mg/l

Persistence:

Soil:

Score: 10

Basis: 75 - 100% disappearance from soils in 4 to 30 years (Prelim.,1991)
T 1/2 from 2 to greater than 15 years (Prelim.,1991)
T 1/2 for volatilization = 100 days (Prelim.,1991)
T 1/2 = 16 to 100 days based upon anaerobic flooded soil die-away study data for 2 soils (SRC,1989)
T 1/2 = 16.6 days to 31.3 years in groundwater based upon anaerobic flooded soil die-away study data for 2 soils (SRC,1989)
T 1/2 = 100 days based upon volatilization (Prelim.,1991)

Water:

Score: 10E

Basis: The calculated half-life for DDT in water based on evaporation is 73.9 hours (Prelim.,1991)
T 1/2 for photolysis in estimated to be greater than 150 years (Prelim.,1991)
In water DDT can be photodegraded, adsorbed to sediments, or biodegraded by organisms (Prelim.,1991)
Volatilization half-lives for DDT in pure water, water from San Francisco bay, the American River, and the Sacramento river are 3.9, 6.5, 6, and 10 hours respectively (Prelim.,1991)
T 1/2 = 7 to 350 days based upon estimated photooxidation half-life in water (SRC,1989)
T 1/2 = 2 to 15.6 years based upon observed rates of biodegradation under aerobic conditions (SRC,1989)

Sediment:

Score: 10Q

Basis: T 1/2 = 16.6 days to 31.3 years in groundwater based upon anaerobic flooded soil die-away study data for 2 soils (SRC,1989)

Air:

Score: 0Q

Basis: The estimated mean residence time for DDT in air is 4 years (Prelim.,1991)
It is subject to photooxidation and reaction with photochemically produced hydroxyl radicals with a half-life of 2 days (Prelim.,1991)
T 1/2 = 17.7 hours to 7.4 days based upon estimated photooxidation half-life in air (SRC,1989)

Bioaccumulation:

Score: 10

Basis: BCF : Common Shiner: 363000 (Prelim.,1991)
BCF : Green Sunfish: 23185-78500 (Prelim.,1991)
BCF : Largemouth Bass: 317000 (Prelim.,1991)
BCF: Northern Redbelly Dace: 363000 (Prelim.,1991)
BCF: Pumpkinseed: 23185-78500 (Prelim.,1991)

Toxicity:

Acute Aquatic:

Score: 10

Basis: Score based on extensive LC50 data for freshwater fish including the striped killifish, largemouth bass, and brown trout:

striped killifish: 96h LC50: 0.001 mg/l
largemouth bass: 96h LC50: 0.002 mg/l
brown trout: 96h LC50: 0.0018 mg/l

Chronic Aquatic:

Score: 10Q

Basis: Score based on EC50s ranging from 5.0 E-04 to 0.1 mg/l for reproductive effects in Daphnia sp.

Daphnia sp.: 14d EC50: reproductive effects: 7.5 E-04 to 6.1 E-04 mg/l
Daphnia sp.: 14d EC50: reproductive effects: 5.0 E-04 mg/l

Phytotoxicity:

Score: 8

Basis: Score based on aquatic data for diatoms and algae. It was reported that algae (*Skeletonema* sp.) and diatoms (*Thallasiosira* sp.) underwent a 36% reduction in oxygen evolution at 0.01 mg/l. Numerous studies support this score.

Chronic Mammalian:

Score: 10

Basis: The score is based on a 27 week study in which a NOAEL of 0.05 mg/kg/day was reported for rats based on liver effects.

1,4-Dichlorobenzene **106-46-7**

Persistence:

Soil:

Score: 10L

Basis: 1,4-DCB can be moderately to tightly adsorbed to soil (Howard,1989)

Leaching from hazardous waste disposal sites in Niagara Falls into adjacent surface waters has been reported, and detection in various groundwaters indicates that leaching can occur (Howard,1989)

Volatilization from soil surfaces may be an important transport mechanism; however, volatilization may be attenuated by tight adsorption or leaching (Howard,1989)

Chemical transformation processes such as hydrolysis, oxidation, or direct photolysis (on soil surfaces) are not expected to occur (Howard,1989)

* $T_{\frac{1}{2}}$ = 4 weeks to 6 months based upon unacclimated aerobic screening test data (SRC,1989)

Water:

Score: 0

Basis: $T_{\frac{1}{2}}$ = 4 weeks to 6 months based upon unacclimated aqueous aerobic biodegradation half life (SRC,1989)

* 1,4-DCB is volatile from water, with an estimated half life of 4.3 hours in a model river 1 meter deep flowing at 1 m/sec with a wind velocity of 3 m/sec at 20°C (Howard,1989)

It may biodegrade under aerobic conditions after acclimation, however it is not expected to biodegrade under anaerobic conditions which may exist in sediments and groundwaters (Howard,1990)

* Biodegradation: 7d: 37-55% (Prelim.,1990)
* 100% degraded in 4 hours under aerobic conditions, and 72 hours for anaerobic conditions (Prelim.,1990)

Volatilization: mesocosm experiment: $T_{\frac{1}{2}}$: 18 days in spring: 10 days in summer: 13 days in winter: seasonal differences explained by hydrodynamics (Prelim.,1990)

1,4-Dichlorobenzene **106-46-7**

Sediment:

Score: 10

Basis:* Monitoring data based on Koc values of 63,000-100,000 and extensive sediment monitoring data in the great lakes area indicate that adsorption to sediment is a major environmental fate process of 1,4-DCB (Howard,1989)

* Its detection in Lake Ontario sediment cores indicate that it has persisted in these sediments since before 1940 (Howard,1990)

Air:

Score: 4

Basis:* $T_{\frac{1}{2}}$ = 8.4 to 83.6 days based upon measured rate data for the vapour phase reaction with hydroxyl radicals in air (SRC,1989)

* 1,4-DCB will exist predominantly in the vapour phase in the atmosphere (Howard,1989)

* The half life for the vapour phase reaction of 1,4-DCB with photochemically produced hydroxyl radicals in the atmosphere has been estimated to be 31 days (Howard,1989)

The detection of 1,4-DCB in rainwater suggests that atmospheric removal via washout is possible (Howard,1989)

Bioaccumulation:

Score: 7

Basis: BCF Rainbow trout: 4d: 214 (Prelim.,1990)

* BCF Rainbow trout: up to 119d: 370-720 (Prelim.,1990)

* BCF Rainbow trout: egg to alevin: 100-250: hatch stage: 1400 (Prelim.,1990)

* BCF Guppy:(Lipid basis): 19d: 1800-1995 (Prelim.,1990)

BCF Bluegill: 10 weeks: 15 (Prelim.,1990)
BCF Rainbow trout: 7d: 79 (Prelim.,1990)
BCF Rainbow trout: 10 weeks: 229 (Prelim.,1990)
BCF Carp: 8 weeks: 100 (Prelim.,1990)
BCF Fathead minnow: 110 (Prelim.,1990)
Log Kow: 3.37 (Prelim.,1990)
Log Kow: 3.39 (Prelim.,1990)
Log Kow: 3.52 (Prelim.,1990)

1,4-Dichlorobenzene **106-46-7**

Toxicity:

Carcinogenicity:

Score: 10

Basis: IARC Group 2B (1987): inadequate evidence for carcinogenicity to humans; sufficient evidence for carcinogenicity to animals
rat, mouse: gastric intubation: renal tubular cell adenocarcinomas in male rats; hepatocellular carcinomas in male and female mice.

3,3'-Dichlorobenzidine 91-94-1

Persistence:

Soil:

Score: 10

Basis:* $T_{\frac{1}{2}}$ = 4 weeks to 6 months based upon estimated unacclimated aqueous biodegradation (SRC,1989)
* No 3,3'-dichlorobenzidine was lost from soil due to volatilization during persistence studies over 32 weeks and 52 weeks under aerobic and anaerobic conditions ...evaporation from water would not be a significant transport process (Prelim.,1990)
* 2% mineralization under aerobic conditions in 32 weeks (Prelim.,1990)
* after a 224 day incubation period under aerobic conditions, 2.35% of the theoretical CO_2 had been released from an initial concentration of 4ppm (Prelim.,1990)

Water:

Score: 0

Basis:* $T_{\frac{1}{2}}$ = 1.5 minutes based upon direct photolysis in distilled water in midday summer sunlight (SRC,1989)
* $T_{\frac{1}{2}}$ = 4.5 minutes based upon direct photolysis in distilled water in midday winter sunlight (SRC,1989)
* it will rapidly sorb to sediments and particulate matter in the water column ...
* it will rapidly photodegrade in surface layers of water ($T_{\frac{1}{2}}$ = 90 seconds) (Prelim.,1990)
after 1 month incubation period at 21°C in the dark, 75% still remained (Prelim.,1990)

Sediment:

Score: *

Basis:* it will rapidly sorb to sediments and particulate matter in the water column (Prelim.,1990)

Air:

Score: 0

Basis:* $T_{\frac{1}{2}}$ = 1.5 minutes based upon direct photolysis in distilled water in midday summer sunlight (SRC,1989)
* $T_{\frac{1}{2}}$ = 4.5 minutes based upon direct photolysis in distilled water in midday winter sunlight (SRC,1989)
* If released into air it would most likely be associated with particulate matter or aerosols ...would probably rapidly photodegrade (Prelim.,1990)

Bioaccumulation:

Score: 7

Basis:* BCF Bluegill: ≈ 500 (Prelim.,1990)
BCF Bluegill: 48h: 265; 120h: 277 (Prelim.,1990)
BCF Bluegill:(edible portion):141 (Prelim.,1990)
* BCF Bluegill:(whole body): 501 (Prelim.,1990)
BCF Bluegill: 132 (Prelim.,1990)
* BCF Bluegill: 550 (Prelim.,1990)
* BCF Bluegill:(whole body) 490-507 (Prelim.,1990)
BCF Bluegill:(edible parts) 114-170 (Prelim.,1990)
* BCF Golden ide: 610 (Prelim.,1990)
Log Kow: 3.02 (Prelim.,1990)
Log Kow: 3.56 (Prelim.,1990)
Log Kow: 3.51 (Prelim.,1990)

Toxicity:

Carcinogenicity:

Score: 10

Basis: Score based on IARC Group 2B rating (see IARC monographs), positive cancer bioassays (including oral and subcutaneous administration in several species) as well as numerous in vitro and in vivo mutagenic assays and other oncogenic transformation assays. See CESARS for complete data list.

Dieldrin 60-57-1

Persistence:

Soil:

Score: 10

Basis: T 1/2 = 175 days to 3 years based upon unacclimated aerobic soil grab sample data and reported half-life in soil based on field data (SRC,1989)
T 1/2 = 7 years (Prelim.,1990)

Water:

Score: *

Basis: Estimated half-life for volatilization from a column 1 meter high at 25°C is 539 days (Prelim.,1990)
T 1/2 for photolysis is approximately 2 months (Prelim.,1990)
T 1/2 for hydrolysis is greater than 4 years (Prelim.,1990)
T 1/2 for water 1 meter deep is 723 days (Prelim.,1990)
T 1/2 for photooxidation = 4.8 hours (Prelim.,1990)
After 8 weeks in a sealed glass jar 100% of the compound stil remained (Prelim.,1990)
T 1/2 for evaporation at 25°C = 12940 hours (Prelim.,1990)
In water it will photorearrange to form photodieldrin, the half-life is approximately 4 months (Prelim.,1990)
T 1/2 for evaporation from pond water = 72 days (Prelim.,1990)
T 1/2 for evaporation from lake water = 57 days (Prelim.,1990)
T 1/2 for evaporation from from river water = 14 days (Prelim.,1990)
T 1/2 for evaporation from distilled and natural waters with gentle agitation is 6 to 9 hours (Prelim.,1990)
The half-life of dieldrin in distilled water is approximately 2 months (Prelim.,1990)
T 1/2 = 175 days to 3 years based upon estimated aqueous aerobic biodegradation (SRC,1989)

Sediment:

Score: *

Basis: Diedrin will strongly adsorb to sediments (Prelim.,1990)
T 1/2 = 1 to 7 days based upon soil and freshwater mud grab sample data (SRC,1989)

Air:

Score: 0E

Basis: T 1/2 = 4 hours to 1.7 days based upon an estimated rate constant for the vapour phase reaction with hydroxyl radicals in air (SRC,1989)

Bioaccumulation:

Score: 10

Basis: BCF: Alewife: 13000 - 77000 (Prelim.,1990)
BCF: Slimy Sculpin: 15000-23000 (Prelim.,1990)

Toxcity:

Acute Aquatic:

Score: 10

Basis: Score based on very high acute toxicity to freshwater fish and aquatic insects (Prelim., 1991):

stonefly: 96h LC50: 5.0 E-04 mg/l
damselfly: 96h LC50: 0.012 mg/l
rainbow trout: 96h LC50: 0.0012 mg/l
goldfish: 96h LC50: 0.0018 mg/l
bluegill: 96h LC50: 0.008 mg/l

Chronic Mammalian:

Score: 10

Basis: Score based on chronic oral NOAELs from several studies (Prelim., 1991):

mouse: oral: 6-10 wks: immunosuppression: LOAEL: 0.75 mg/kg/d: NOAEL: 0.075 mg/kg/d.
rat: oral: 2 yr: liver weight increases: LOAEL: 0.05 mg/kg/d: NOAEL: 0.005 mg/kg/d.
monkey: oral: 54d: impaired learning and EEG changes: 0.01 or 0.1 mg/kg/d.
rat: oral: lifetime: increased liver to body weight ratios: LOAEL: 0.05 mg/kg/d: NOAEL: 0.005 mg/kg/d.
rat: oral: 2 yrs: liver lesions: 0.005 mg/kg/d.

Hexachlorobenzene 118-74-1

Persistence:

Soil:

Score: 10

Basis:* if HCB is released to soil it is likely to remain there for extended periods of time due to its strong adsorption to soil (a half life of 1530 days has been reported) (Howard,1989)
* Little biodegradation will occur and transport to groundwater is expected to be slow, depending on the organic carbon content of the soil (Howard,1989)
* $T_{\frac{1}{2}}$ estimated based upon unacclimated aerobic grab sample data = 2.7 to 5.7 years (SRC,1989)
* No loss when stored in a covered container for 12 months (Prelim.,1990)
* 55% loss of HCB from top 2 centimeters in 2 weeks, no loss from soil 2-4 cm deep in 19 months (Prelim.,1990)
* In laboratory experiments incorporating 10 kg/ha of HCB the half life was estimated at 4.2 years; volatilization is the major loss mechanism (Prelim.,1990)
* In a 21 day study where HCB was applied to soil cores there was <1% loss due to volatilization or leaching and no degradation occured (Prelim.,1990)

Water:

Score: 0

Basis:* HCB released to water will evaporate rapidly with a measured half life of 8 hours (Howard,1989)
Adsorption to sediments and bioconcentration are also important pathways (Howard,1989)
Hydrolysis and biodegradation will not be important pathways in water (Howard,1989)
$T_{\frac{1}{2}}$ estimated for aqueous aerobic biodegradation = 2.7 to 5.7 years (SRC,1989)

Hexachlorobenzene **118-74-1**

Water:

Basis: HCB showed no degradation by water or sediment microbes (Prelim.,1990)
* $T_{\frac{1}{2}}$ for volatilization = 31 to 41 hours (Prelim.,1990)
* $T_{\frac{1}{2}}$ measured for volatilization from water column = 8 hours (Prelim.,1990)
27% of HCB applied to a pond and sediments was still present after 30 weeks (Prelim.,1990)

Sediment:

Score: 10L

Basis: * 27% of HCB applied to a pond and sediments was still present after 30 weeks (Prelim.,1990)
* HCB showed no degradation by water or sediment microbes (Prelim.,1990)
* Adsorption to sediments and bioconcentration are important pathways (Howard,1989)

Air:

Score: 10

Basis: It can exist in both the vapour phase and adsorbed state, however, monitoring studies have shown that the vapour phase should strongly dominate (Howard,1989)
* Degradation of HCB in the atmosphere appears to be extremely slow with an estimated photooxidation half life of 2 years (Howard,1989)
* $T_{\frac{1}{2}}$ estimated for photooxidation = 156.4 days to 4.2 years (SRC,1989)

Bioaccumulation:

Score: 10

Basis:* BCF Fathead minnow: 35000 (Prelim.,1990)
BCF Fish: 1160-3740 (Prelim.,1990)
* BCF Rainbow trout: 105d: 20000 (Prelim.,1990)
* BCF Guppy (Lipid cont.): 290000 (Prelim.,1990)
* BCF Fathead minnow: 22000 (Prelim.,1990)
* BCF Fathead minnow: 31000 (Prelim.,1990)
* BCF Largemouth bass: 18214-44437 (Prelim.,1990)
BCF Trout: 7762 (Prelim.,1990)
Log Kow: 5.50 (measured) (Prelim.,1990)
Log Kow: 6.39 (Prelim.,1990)
Log Kow: 5.98 (Prelim.,1990)
Log Kow: 5.8 (Prelim.,1990)
Log Kow: 5.31 (Prelim.,1990)
Log Kow: 6.18 (Prelim.,1990)

Hexachlorobenzene **118-74-1**

Toxicity:

Mammalian Sublethality (oral):
Score: 10

Basis: Score based on studies in 2 species where oral NOAELs were observed to be <0.1 mg/kg:

pig (male): oral: 90d: 0.05 - 50 mg/kg/d: porphyria and death at highest dose: induction of microsomal liver enzymes and increased liver weight at 5 mg/kg: NOAEL 0.05 mg/kg/d.
rat: oral: unreported duration: NOEL 0.04 mg/kg/d.
rat: oral(gavage): 29 wk: increased liver weight: 0.05 mg/kg twice weekly.

Carcinogenicity:
Score: 10

Basis: Score based on IARC Group 2B: sufficient evidence for carcinogenicity to animals: positive animal results in cancer bioassays in three species (rat, hamster, mouse): some limited human evidence (see IARC). Evidence of DNA damage in bacteria. See CESARS for complete data list.

Persistence:

Soil:

Score: 10W

Basis: incubation study showed 10% remaining after 56 days (Prelim.,1987)

* $T_{\frac{1}{2}}$ = 80 to 135 days in aerobic soil die-away test (SRC,1989)

$T_{\frac{1}{2}}$ = 7 to 40 days based upon anaerobic soil die-away test (SRC,1989)

After 2 weeks in unsterilized, submerged Casiguran sandy loam, the concentration of α-HCH declined from about 16 ppm to less than 1 ppm compared to a decline from 18 ppm to 15 ppm for a sterilized preparation (Howard,1991)

* Fifteen years following the application of technical hexachlorocyclohexane to a sandy loam in Nova Scotia, 4% of the applied α-HCH remained in the soil, of this amount 92% was found between 0 and 20 cm. The soil was under cultivation yearly throughout the fifteen years, increasing the likelihood that volatilization may have occurred (Howard,1991)

Water:

Score: 10E

Basis: $T_{\frac{1}{2}}$ = 13.8 days based upon hydrolysis half life of gamma-hexachlorocyclohexane (SRC,1989)

* Hydrolysis half life = 2 years (Prelim.,1987)

Aerobic biodegradation is expected to be of minor importance (Howard,1991)

* It is expected to volatilize slowly from water at a rate dependant on the rate of diffusion through air (Howard,1991)

The volatilization half life from a model river (1 meter deep flowing at 1 m/sec with a wind velocity of 3 m/sec) has been estimated to be about 6 days (Howard,1991)

* The volatilization half life from a model pond, which considers the effect of adsorption, has been estimated to be approximately 500 days (Howard,1991)

Sediment:

Score: *

alpha-Hexachlorocyclohexane **319-84-6**

Air:

Score: 0E

Basis:* $T_{\frac{1}{2}}$ = 9.24 to 92.4 hours based upon estimated photooxidation half life in air (SRC,1989)
It is expected to exist in both the vapour phase and particulate phase in ambient air (Howard,1991)
* Vapour phase reactions with photochemically produced hydroxyl radicals may be an important fate process (Howard,1991)
* The atmospheric half life based on the above reaction is estimated to be 2.3 days (Howard,1991)
α-HCH that is associated with particulate matter and aerosols in the atmosphere should be subject to gravitational settling and washout by rain (Howard,1991)

Bioaccumulation:

Score: 7

Basis:* BCF Guppy: 500 (Prelim.,1987)
* BCF Guppy: 540 (Prelim.,1987)
* BCF Guppy fed contaminated Daphnia 420 - 1000 (Prelim.,1987)
* BCF Golden orfe: 1216 (Howard,1991)
* BCF Brown trout: 605 (Howard,1991)
BCF Carp: 330 (Howard,1991)
Log Kow: 3.81 (Prelim.,1987)
Log Kow: 3.80 (Howard,1991)

Toxicity:

Carcinogenicity:

Score: 10

Basis: Score based on IARC rating (Group 2B) indicating sufficient evidence for carcinogenicity to animals:

rat: oral: liver: neoplastic effects
rat: oral: liver: equivocal tumorigenic agent
rat: liver: positive carcinogen

gamma-Hexachlorocyclohexane (Lindane) **58-89-9**

Persistence:

Soil:

Score: 10

Basis:* $T_{\frac{1}{2}}$ for hydrolysis = 13.8 to 240 days (SRC,1989)
* $T_{\frac{1}{2}}$ for aerobic soil die-away study data = 31 to 413 days (SRC,1989)
$T_{\frac{1}{2}}$ for anaerobic flooded soil die-away study data = 5.9 to 30 days (SRC,1989)
* From moist, aerated soil, 62% of applied lindane was recovered after 105 days (Howard,1991)
Incubation of aerobic and anaerobic soil suspensions for three weeks resulted in disappearence of 0 and 63.8% respectively (Howard,1991)
Lindane is expected to leach slowly into groundwater (Howard,1991)
* $T_{\frac{1}{2}}$ estimated for soil = 1.2 to 2 years (Prelim.,1988)
* Biodegradation in soil 75 to 100% lost after 3 to 10 years (Prelim.,1988)
* in a 140 day test in aerated soil 17.8% ^{14}C released as $^{14}CO_2$ (Prelim.,1988)
In moist soil 50% and 10% remained after 6 hours and 6 days, respectively (Prelim.,1988)
In dry soil 88% remained after 50 hours (Prelim.,1988)
After 45 days less than 50% had leached into groundwater (Prelim.,1988)

Water:

Score: 10E

Basis:* $T_{\frac{1}{2}}$ for hydrolysis = 13.8 to 240 days (SRC,1989)
After 16 weeks, less than 30% of the applied Lindane remained in unsterilized natural waters in capped bottles (Howard,1991)
* River, lake, and groundwater half lives for Lindane were estimated from degradation data in these bodies to be 3 to 30, 30 to 300, and greater than 300 days, respectively (Howard,1991)
Extensive monitoring data has shown that Lindane can partition from the water column to suspended and bottom sediments (Howard,1991)

The role of of particle transport in the transport of Lindane to sediment was considered to be small when compared to diffusion (Howard,1991)

* The estimated volatilization half life for lindane = 115 days (Prelim.,1988)
* In water 1 meter deep the estimated half life for volatilization = 191 to 692 days (Prelim.,1988)
* The estimated volatilization half life from a quarry is 8 years (Prelim.,1988)
* Assuming a body of water has no movement and a depth of 1 meter, the volatilization half life is estimated to be 191 days (Howard,1991)

The volatilization half life from a model river 1 meter deep, flowing at 1 m/sec, with a wind speed of 3 m/sec is estimated to be 22 days (Howard,1991)

Sediment:

Score: 10

Basis: $T_{\frac{1}{2}}$ for anaerobic flooded soil die-away study data = 5.9 to 30 days (SRC,1989)

* estimated half life of lindane in sediments is 4 to 5 years (Prelim.,1988)
* In a water column and sediment study 75% was recovered after 100 days (Prelim.,1988)

Air:

Score: 0E

Basis:* $T_{\frac{1}{2}}$ for estimated rate constant for reaction with hydroxyl radicals in air = 9.24 hours to 3.85 days (SRC,1989)

$T_{\frac{1}{2}}$ estimated based upon washout by rain and dry deposition = 17 weeks (Howard,1991)

* Lindane is expected to exist almost entirely in the vapour phase in ambient air (Howard,1991)
* The estimated half life for reactions with hydroxyl radicals in the atmosphere is approximately 2.3 days (Howard,1991)

gamma-Hexachlorocyclohexane (Lindane) **58-89-9**

Bioaccumulation:
Score: 7

Basis: BCF Fathead minnow (32d): 180 (Prelim.,1988)
BCF Rainbow trout (fry): 319 (Prelim.,1988)
* BCF Topmouth Gudgeon: 1246 (Prelim.,1988)
* BCF Mosquitofish: 560 (Prelim.,1988)
* BCF N. Brook Silverside: 1613 (Prelim.,1988)
BCF Snail: 456 (Prelim.,1988)
Log Kow: 3.72 (Prelim.,1988)
Log Kow: 3.61 (Prelim.,1988)
Log Kow: 3.89 (Prelim.,1988)

Toxicity:

Acute Aquatic:
Score: 10

Basis: Score based on very high toxicity of lindane to aquatic organisms i.e fish 96h-LC50s range from 0.0017 to 0.0320 mg/l; other aquatic invertebrates 0.0056 to 0.07 mg/l.

Sublethal Mammalian (Inhalation):
Score: 10

Basis: Score based on minimal pathology noted for several species after exposure to 0.7 mg/m^3 vapour for one year:

several sp : inhalation: 7h/d: 5 d/wk,1 yr: minimum pathology: 0.7 mg/m^3.
rat: inhalation: 655 d continuous: no path: 0.19 mg.m^3.

Carcinogenicity:
Score: 10

Basis: Score based on IARC grouping 2B and positive Genetox Program results. See CESARS for data set.

Mercury **7439-97-6**

Persistence:

Soil:
Score: 10

Basis: Mercury is an element

Water:
Score: 10

Basis: Mercury is an element

Sediment:
Score: 10

Basis: Mercury is an element

Air:
Score: 10

Basis: Mercury is an element

Bioaccumulation:
Score: 10Q

Basis: The form of mercury is important in the pattern of accumulation (OMOE,1987)
* Bioconcentration factors for methylmercury range from 4000 to 85,000 (OMOE,1987)

Toxicity:

Acute Aquatic:
Score: CMR 7

Basis: The acute (≤ 96h) LC50s for vertebrate test populations have been reported as ranging from 0.030 to 0.42 mg/l and for invertebrates from 0.0044 to 0.370 mg/l for inorganic mercury (U.S.EPA Ambient Water Quality Criteria for Mercury-1984. Office of Water Regulations and Standards, Washington,D.C.).

Mercury **7439-97-6**

Reproduction:

Score: CMR 7

Basis: well established as capable of reproductive/teratogenic effects:
rat: inhalation: Lowest published toxic concentration: 0.0089 mg/l/24h: paternal effects: spermatogenesis (including genetic material, sperm morphology).
rat: inhalation: Lowest published toxic concentration: 0.0749 mg/l/24h: fertility.
rat: inhalation: Lowest published toxic concentration: 1.0 mg/l/24h: female 1-20 days after conception: embryo or fetus: fetotoxicity (except death, e.g. stunted fetus).

Persistence:

Soil:

Score: *

Basis: Studies with mirex contaminated anaerobic soils and anaerobic lake sediments showed virtually no bacterial degradation (Prelim.,1991)

Water:

Score: *

Basis:

Sediment:

Score: 10Q

Basis: Mirex contained in sediments may remain bioavailable for 200 to 600 years (Prelim.,1991)
Studies with mirex contaminated anaerobic soils and anaerobic lake sediments showed virtually no bacterial degradation (Prelim.,1991)

Air:

Score: *

Basis:

Bioaccumulation:

Score: 10

Basis: BCF:Fathead Minnow:60D: 7300-15000 (Prelim.,1991)
BCF:Fathead Minnow:90D: 8000-19000 (Prelim.,1991)
BCF:Fathead Minnow:32D: 18100 (Prelim.,1991)
BCF:Fathead Minnow:120D: 13800-28000(Prelim.,1991)

Toxicity:

Phytotoxicity:

Score: 10

Basis: Score based on several studies with algae and on the effects of mirex on plankton. The most sensitive effect reported was in a 96h algae study where decreased population size was apparent at 9.0 E-04 mg/l. (Prelim.,1991):

algae: 96h: 16.3% decrease in population size: 9.0 E-04 mg/l
plankton: 5,10,15,20d: photosynthesis inhibited by 16, 10, 33, and 19%: 1.0 E-03 mg/l

Chronic Mammalian:

Score: 8

Basis: Score based on oral studies of NOELs in the rat and dog (Prelim., 1991):

dog: oral: 90d: increased mortality, increased SAP, enlarged liver, decreased spleen size, LEL: 2.5 mg/kg/d: NOEL: 0.5 mg/kg/d.
rat: oral: 13 wks: significantly enlarged liver: 4 mg/kg/d in males: 16 mg/kg/d in females: no effects in males or females at 1.0 mg/kg/d.

Pentachlorophenol 87-86-5

Persistence:

Soil:

Score: 4

Basis:* $T_{\frac{1}{2}}$ based upon estimated aqueous aerobic biodegradation half life = 23 to 178 days (SRC,1989)
* $T_{\frac{1}{2}}$ for microbial degradation = 12 days (Prelim.,1990)
* $T_{\frac{1}{2}}$ for biodegradation ≈ 2 to 4 weeks (Prelim.,1990)
100% microbial degradation in > 72 days (Prelim.,1990)
* $T_{\frac{1}{2}}$ for biodegradation in soil is weeks to months (Prelim.,1990)
Photodegradation is not a significant process in soil (Prelim.,1990)
90% removal of 100ppm application in 10 days; 10% removal of 1000ppm application over same length of time (Prelim.,1990)
Photolysis and hydrolysis do not appear to be significant processes in soil (Howard,1991)
Considerable amounts of the formulated pesticide have been shown to volatilize (Howard,1991)

Water:

Score: 0

Basis:* Pentachlorophenol released into water will dissociate at ambient pHs. The dissociated form will photodegrade with a half life of hours to days (Howard,1991)
* $T_{\frac{1}{2}}$ based upon aqueous photolysis half life = 1 hour to 4.6 days (SRC,1989)
* $T_{\frac{1}{2}}$ for photodegradation at surface = 0.33 hours (Prelim.,1990)
* $T_{\frac{1}{2}}$ for photolysis = 3.02 to 43.1 hours depending on depth, 0.5-13.8 cm (Prelim.,1990)

Pentachlorophenol **87-86-5**

Water:

$T_{\frac{1}{2}}$ calculated for volatilization in water 1 meter deep = 125 days (Prelim.,1990)

Hydrolysis and volatilization are not considered significant pathways for pentachlorophenol in water (Prelim.,1990)

* Photolysis, 50% degraded in 48 hours,100% degraded in 10 days at pH 7.3 (Prelim.,1990)

In a natural stream virtually no aerobic biodegradation was observed in 40 days (Prelim.,1990)

In an artificial stream microbial degradation became significant after dosing for 3 weeks, this became the dominant removal process accounting for 26-46% (Prelim.,1990)

Sediment:

Score: 10L

Basis:* $T_{\frac{1}{2}}$ based upon unacclimated anaerobic sediment grab sample = 42 days to 4.2 years (SRC,1989)

* adsorption to sediment will be considerable (Prelim.,1990)

Air:

Score: 4E

Basis:* $T_{\frac{1}{2}}$ based upon estimated photooxidation half life = 5.8 to 58 days (SRC,1989)

* A potential exists for photolysis based on the UV spectrum for the nondissociated form which shows some absorption at wavelengths greater than 290 nm (Prelim.,1990)

Pentachlorophenol associated with particulate matter in air will be subject to gravitational settling (Howard,1991)

Vapour phase pentachlorophenol will be lost to photolysis, and to a lesser extent, reaction will photochemically produced hydroxyl radicals. the loss from these processes in mid-day summer sunshine is 6.2 and 1.5%/hr, respectively (Howard,1991)

The half lives calculated using the above values for photolysis and photooxidation are 8.1 hours and 33.3 hours, respectively

Pentachlorophenol **87-86-5**

Bioaccumulation:

Score: 7

Basis: BCF Goldfish: pH 10; 2: pH 7; 56: pH 5; 132 (Prelim.,1990)
* BCF Fathead minnow: 776 (Prelim.,1990)
* BCF Fathead minnow: 32d: 281-1066 (Prelim.,1990)
* BCF Rainbow trout: 251-5370 (Prelim.,1990)
* BCF Rainbow trout: liver: 615 (Prelim.,1990)
BCF Rainbow trout: muscle: 39 (Prelim.,1990)
BCF Rainbow trout: muscle: 40 (Prelim.,1990)
BCF Rainbow trout: whole body: 242 (Prelim.,1990)
BCF Mosquitofish: 295 (Prelim.,1990)
BCF Mosquitofish: 132 (Prelim.,1990)
* BCF Golden orfe: 24h: 350; 3d: 1100(Prelim.,1990)
BCF Carp: static: 300-400 (Prelim.,1990)
BCF Bluegill: 8d: muscle: 13 (Prelim.,1990)
* BCF Goldfish: 0.2 mg/L: 475; 580(Prelim.,1990)
* BCF Goldfish: 0.1 mg/L: 120hr: 1000(Prelim.,1990)
Log Kow: 5.01 (Prelim.,1990)
Log Kow: 5.12 (Prelim.,1990)

Toxicity:

Acute Aquatic:

Score: 10

Basis: Score primarily based on fish 96 h LC50s:

larval Carp: 0.0095 mg/l;
Chinook salmon: 0.068 mg/l;
Channel catfish: 0.054 mg/l;
Rainbow trout: 0.052 mg/l.

Nonmammalian Aquatic

Score: 10E

Basis: Score based on carp MATC(est) of 0.0005 mg/l. Most other species 10 to 50x higher.

Perylene **198-55-0**

Persistence:

Soil:
Score: *

Water:
Score: *

Sediment:
Score: 10E

Basis:* based on analogy to other PAHs with 4 or more rings which biodegrade slowly in contaminated sediment ($T_{\frac{1}{2}}$ > 7000 hours), in clean sediment 10 to 400 times longer (Prelim.,1987)

Air:
Score: *

Bioaccumulation:
Score: 7

Basis:* BCF Fathead minnow 1112 (AQUIRE,1990)
* Log BCF Daphnia magna (24h): 3.8567 (7189) (Newsted et al., 1987)
Log Kow: 6.06 (calc.) (Prelim.,1987)

Toxicity:

Acute Aquatic:
Score: 10Q

Basis: Score based on acute toxicity to Daphnia sp.. A Q tag was assigned due to some questionable data (see anthracene):

Daphnia sp.: UV-LT50: 18.33h: 0.001 mg/l

Phenanthrene **85-01-8**

Persistence:

Soil:

Score: 10W

Basis:* $T_{\frac{1}{2}}$ = 16 to 200 days based upon aerobic soil die-away test (SRC,1989)
$T_{\frac{1}{2}}$ for biodegradation = 26 days at 15 to 25°C (Prelim.,1987)
$T_{\frac{1}{2}}$ for biodegradation at > 25°C = 2.5 days (Prelim.,1987)

Water:

Score: 7W

Basis: $T_{\frac{1}{2}}$ = 3 to 25 hours based upon aqueous photolytic half-life (SRC,1989)
$T_{\frac{1}{2}}$ = 5 to 10 hours for photodegradation under natural light in mixed acetone-water or carbon tetrachloride-water solutions (Nagata et al., 1977; Neff, 1985)
* Direct photolysis in a 5 metre deep inland waterbody with partitioning to sediment, $T_{\frac{1}{2}}$ = 69 days; without partitioning $T_{\frac{1}{2}}$ = 59 days (Zepp et al., 1979)
$T_{\frac{1}{2}}$ estimated for photolysis = 8.4 hours (Prelim.,1987)
* $T_{\frac{1}{2}}$ biodegradation = 24 to 11000 days (much longer at lower temperatures (Prelim.,1987)
* $T_{\frac{1}{2}}$ for volatilization = 9.4 hours, 13.15 hours, and 4696.13 hours from a stream, river and lake respectively (Prelim.,1987)

Sediment:

Score: *

Air:

Score: 0

Basis:* $T_{\frac{1}{2}}$ = 2.01 to 20.1 hours based upon photooxidation half life in air (SRC,1989)
* $T_{\frac{1}{2}}$ oxidation by ozone = 9.4 hours (Prelim.,1987)
* $T_{\frac{1}{2}}$ for oxidation = 1.67 days (Prelim.,1987)

Phenanthrene **85-01-8**

Bioaccumulation:
Score: 7

Basis:* Log BCF Fathead minnow: 3.42 (2630) (Ma et al.,1990)
* BCF Fathead minnow: 5225 (Oris et al.,1987)
* Log BCF Golden Ide: 3.25 (1778) (Ma et al.,1990)
Log BCF Daphnia magna (24h): 2.5105 (324) (Newsted et al.,1987)
BCF Deposit feeding clam: 10.3 (Prelim.,1987)
BCF Estuarine clam: (24 hour): 32 (Prelim.,1987)
Log Kow: 4.46 (Ma et al.,1990)
Log Kow: 4.50 (Prelim.,1987)
Log Kow: 4.60 (Prelim.,1987)

Toxicity:

Acute Aquatic:
Score: 10L

Daphnia sp.: 96h LC50: 0.10 mg/l

Polychlorinated Biphenyls n/a

Persistence:

Summary Score: 10E

Basis: PCB's are considered very persistent in the environment (Prelim.,1987)

Soil:

Score: *

Basis: PCB's are rapidly adsorbed onto solids, especially organic matter (U.S. EPA,1981)
Aroclor 1260 was not degraded by any soil type in a 112 day study using soil from 1) shade tobacco field 2) swamp 3) corn field 4) soil-pine forest 5) litter-pine forest 6) soil-hardwood forest 7) litter-hardwood forest 8) apple orchard (control) (CESARS,1989)

Water:

Score: 10E

Basis:
* Hydrolysis is not an important process (U.S. EPA,1981)
* Slow volatilization is the cause of global distribution of PCB's, but may be inhibited by adsorption (U.S. EPA,1981)
* Gradually biodegraded (Prelim.,1987)

3.6% of Aroclor 1016 was lost to volatilization in a 24 hour test (U.S. EPA,1979)
The volatilization loss after a 12 week test was about 67% for Aroclor 1260 (CESARS,1989)
Evaporation loss over 6 hours at 100°C = 1 to 1.5% for Aroclor 1221 (U.S. EPA,1979)
Evaporation loss over 6 hours at 100°C = 1 to 1.5% for Aroclor 1232 (U.S. EPA,1979)
Evaporation loss over 6 hours at 100°C = 0 to 0.4% for Aroclor 1242 (U.S. EPA,1979)
Evaporation loss over 6 hours at 100°C = 0 to 0.3% for Aroclor 1248 (U.S. EPA,1979)
Evaporation loss over 6 hours at 100°C = 0 to 0.2% for Aroclor 1254 (U.S. EPA,1979)
Evaporation loss over 6 hours at 100°C = 0 to 0.1% for Aroclor 1260 (U.S. EPA,1979)
The calculated evaporation half life from water 1 meter deep at 25°C is 10.2 hours for Aroclor 1260 (CESARS,1989)

Polychlorinated Biphenyls n/a

Sediment:

Score: 10E

Basis:* PCB's are rapidly adsorbed onto solids, especially organic matter, and are often immobilized in sediments, but may reenter solution (U.S. EPA,1981)

* The persistence of these chemicals makes resolution possible for years after they have entered the sediments (U.S. EPA,1979)

Air:

Score: *

Basis: Slow volatilization is the cause of global distribution of PCB's, but may be inhibited by adsorption (U.S. EPA,1981)

Oxidation is not an important process (U.S. EPA,1981)

Bioaccumulation:

Score: 10

Basis: **Aroclor 1016**

BCF Fathead minnow: 32d: 42,500 (Veith et al.,1979)

* BCF Brown Bullhead: 17000,23000 (Prelim.,1987)

BCF Pumpkinseed: 14700 (Prelim.,1987)

BCF Creek chubsucker (Prelim.,1987)

BCF Yellow perch: 10600 (Prelim.,1987)

Log Kow: 4.38 (U.S. EPA,1979)

Log Kow: > 5.58 (U.S. EPA,1979)

Basis: **Aroclor 1221**

Log Kow: 2.8 (Prelim.,1987)

Log Kow: 4.09 (U.S. EPA,1979)

Basis: **Aroclor 1232**

Log Kow: 3.2 (est.) (Prelim.,1987)

Log Kow: > 4.54 (U.S. EPA,1979)

Basis: **Aroclor 1242**

BCF Fathead minnow: > 100,000 (Prelim.,1987)

Log Kow: 4.11 (Prelim.,1987)

Log Kow: 5.58 (U.S. EPA,1979)

Basis: **Aroclor 1248**

BCF Fathead minnow: 120,000 (Prelim.,1987)

* BCF Fathead minnow: 70,500 (Prelim.,1987)

Log Kow: 5.11 (est.) (Prelim.1987)

Log Kow: 5.75 (Prelim.,1987)

Log Kow: 6.11 (U.S. EPA,1979)

Basis: **Aroclor 1254**

BCF Fathead minnow: 240h: 109,000 to 238,000 (Prelim.,1987)

* BCF Brook trout: 1076 to 47,333 (Prelim. 1987)

* Log Kow: 6.03 (Prelim.,1987)

Polychlorinated Biphenyls n/a

Basis: **Aroclor 1260**
BCF Fathead minnow: 160,000-270,000 (Prelim.,1987)
* BCF Fathead minnow: 194,000 (CESARS,1989)
Log Kow: > 6.11 (U.S. EPA,1979)
Log Kow: 7.14 (est.) (CESARS,1989)

Toxicity

Acute Aquatic Summary:
Score: 10

Basis: Score based on acute toxicity of PCBs to fish and other aquatic organisms:

Rainbow trout: aroclor 1016: 96h LC50: 0.135 mg/l
Fathead minnow: aroclor 1242: 96h LC50: 0.015 mg/l
Fathead minnow: aroclor 1254: 96h LC50: 0.033, 0.0077 mg/l
numerous aquatic species: aroclor 1242: 96h LC50: < 0.1 mg/l
numerous aquatic species: aroclor 1254: 96h LC50: < 0.1 mg/l
Rainbow trout, Bluegill, Channel catfish: aroclor 1260: durations > 240 h: LC50: 0.051-0.512 mg/l

Nonmammalian Summary:
Score: 10

Basis: score based on aquatic organism data:

Daphnia sp.: aroclor 1248: 304h EC50: 0.025ppm
Daphnia sp.: aroclor 1254: 336h EC50: 0.0013-0.024 ppm
Daphnia sp.: aroclor 1260: 304h EC50: 0.036 mg/l
Fathead minnow: aroclor 1248: 720h EC50: 0.0047 ppm
Fathead minnow: aroclor 1254: MATC 0.0029 ppm
Fathead minnow: aroclor 1260: MATC 0.0012 mg/l
Bluegill: aroclor 1248: 720h EC50: 0.078 ppm
Trout: aroclor 1254: 48d: MATC: 0.001 ppm

Carcinogenicity:
Score: 10

Basis: score based on IARC rating (Group 2A) for all PCBs indicating they are probable human carcinogens with sufficient evidence of carcinogenesis in animals.

Polychlorinated dibenzo-p-dioxins and furans **n/a**

Persistence:

Soil:

Score: 10

Basis:* PCDDs are persistent in soil with a half life of greater than 10 years (CESARS,1990)
Tightly bound to soil, sediment, and carbonaceous material (CESARS,1990)

Basis:* $T_{\frac{1}{2}}$ > 10 years (Prelim.,1989)
* P5CDDs are resistant to photolysis and are therefore persistant (Prelim.,1989)
P5CDDs are tightly bound to carbonaceous material (Prelim.,1989)

Basis: PCDFs are subject to oxidation and hydrolysis (Prelim.,1989)

2378tcdd Basis:* $T_{\frac{1}{2}}$ = 1.15 to 1.62 years based upon test data from two soil die-away tests (SRC,1989)
* Microbes cannot contribute quickly or efficiently to the decontamination of 2,3,7,8-TCDD in soil although slow degradation might take place (OMOE,1985)
* Loss due to volatilization from soil is limited, with only 10% of T_4CDD released on soil being detected in the air above after application (OMOE,1985)

Water:

Score: 10

Basis: Theoretically it is subject to hydrolysis (CESARS,1990)
More resistant to photolysis than mono- , di- and tri- congeners and therefore more persistent (CESARS,1990)

2378tcdd Basis:* $T_{\frac{1}{2}}$ = 1.15 to 1.62 years based upon estimated unacclimated aqueous aerobic biodegradation (SRC,1989)
* The half life for volatilization is 5.5 and 12 years for a pond and a lake respectively (OMOE,1985)
The estimated half life for volatilization from a 10 cm deep pond is 2 days (OMOE,1985)
* The estimated half life for volatilization from a 1 meter deep pool is 200 days (OMOE,1985)
Volatilization is not likely to be the major route through which 2,3,7,8-T_4CDD is removed from water (OMOE,1985)
* In a study using an outdoor pond the half life was estimated to be 1 year (OMOE,1985)

Polychlorinated dibenzo-p-dioxins and furans n/a

Sediment:

Score: 10L

Basis: * Core samples indicate that PCDDs and PCDFs have persisted in Lake Huron sediments since the 1940's. The sediment deposition rate was estimated at 0.15 cm/year and PCDDs and PCDFs were detected to a depth of 12 cm (Czuczwa et al.,1984)

p5dd Basis: * P5CDDs and PCDFs may persist in sediments for decades (Prelim.,1989)

* $T_{\frac{1}{2}}$ in sediment = 1 to 2 years (Prelim.,1989)

2378tcdd Basis: * $T_{\frac{1}{2}}$ for lake water with sediment = 550 to 590 days (Prelim.,1987)

Air:

Score: 0E

t7cdd Basis: More resistant to photolysis than mono- , di- and tri- congeners and therefore more persistent (CESARS,1990)

2378tcdd Basis:* $T_{\frac{1}{2}}$ = 22.3 hours to 9.3 days based upon estimated photooxidation half life (SRC,1989)

* UV light is effective in degrading dioxins in the atmosphere (OMOE,1985)

Bioaccumulation:

Score: 10W

Basis: 1,2,3,4,6,7,8-H_7CDD
BCF Rainbow trout: 1059 (OMOE,1990)
BCF Rainbow trout: 1790 (OMOE,1990)
BCF Fathead minnow: 513 (OMOE,1990)
BCF Fathead minnow: 515 (OMOE,1990)

Basis: Log Kow: (N.S.I.): 7.62 (OMOE,1990)

1,2,3,4,7,8-H_6CDD [39227-28-6]
BCF Rainbow trout: 1715 (OMOE,1990)
BCF Rainbow trout: 2840 (OMOE,1990)
BCF Fathead minnow: 2630 (OMOE,1990)
BCF Fathead minnow: 5834 (OMOE,1990)
Log Kow: 7.80 (OMOE,1990)
Log Kow: 10.22 (OMOE,1990)

1,2,3,7,8,9-H_6CDD [19408-74-3]
BCF Guppy: 900 (OMOE,1990)

Basis: 1,2,3,4,7-P_5CDD
BCF Rainbow trout: 810 (OMOE,1990)
BCF Fathead Minnow: 1647 (OMOE,1990)
BCF Fathead Minnow: 1220 (OMOE,1990)

1,2,3,7,8-P_5CDD [40321-76-4]
BCF Guppy: 7700 (OMOE,1990)
Log Kow: 7.80 (OMOE,1990)

Polychlorinated dibenzo-p-dioxins and furans **n/a**

1,2,3,7,9-P_5CDD
BCF Guppy: 1600 (OMOE,1990)
2,3,4,7,8-P_5CDD
BCF Guppy: 5000 (OMOE,1990)
Basis: 1,2,3,7,8-P_5CDF
BCF Guppy: 2400 (OMOE,1990)
2378tcdd Basis: BCF Mosquitofish: 4075 (Prelim.,1987)
BCF Fathead minnow: 2500 (Prelim.,1987)
* BCF Mosquitofish: 240-15500 (OMOE,1990)
BCF Catfish: 490-6800 (OMOE,1990)
* BCF Rainbow trout: 26707 (OMOE,1990)
BCF Guppy: 13000 (OMOE,1990)
Log Kow: 7.9 (Prelim.,1987)
Basis: 1,2,3,7-T_4CDD
BCF Rainbow trout: 874-1577 (OMOE,1990)
BCF Fathead minnow: 2018-2458 (OMOE,1990)
1,3,6,8-T_4CDD
BCF Rainbow trout: 1400-2938 (OMOE,1990)
BCF Fathead minnow: 5565-5840 (OMOE,1990)
1,2,3,4-T_4CDD
Log Kow: 7.18 (OMOE,1990)
Log Kow: 6.60 (OMOE,1990)
2378tcdf Basis:* BCF Rainbow trout: 2455-6049 (OMOE,1990)
BCF Guppy: 6600 (OMOE,1990)
Log Kow: 5.82 (OMOE,1990)
Log Kow: (est.): 6.19 (Ma et al.,1990)

Toxicity

Acute Summary:
Score: 10

Basis: Score primarily based on high acute oral toxicity in many species:

2,3,7,8-tetrachlorodibenzo-p-dioxin **1746-01-6**

guinea pig: oral LD50: 0.0006 mg/kg
rat: oral LD50 0.022 mg/kg
rabbit: oral LD50: 0.115 mg/kg
mouse: oral LD50: 0.114 mg/kg
rabbit: skin LD50: 0.272 mg/kg
Rainbow trout: dietary exposure: 2.3 mg/kg: 88% mortality after 71 days
mosquito fish: LC: 0.003 ug/l: 14 days

hexachlorodibenzo-p-dioxins (mixed isomers) **34465-46-8**

guinea pig: oral: LD50: 0.07 - 0.1 mg/kg
mouse: oral: LD50: 0.83 - 1.4 mg/kg
Toxic Equivalent Factor of 0.1 relative to 2,3,7,8 T_4CDD

Polychlorinated Dibenzo-p-dioxins and -furans n/a

pentachlorodibenzo-p-dioxins (mixed isomers) 36088-22-9

guinea pig: oral LD50: 3.1 ug/kg (1,2,3,7,8-P5CDD)
guinea pig: oral LD50: 1.13 mg/kg (1,2,4,7,8-P5CDD)
mouse: oral LD50: 337.5 ug/kg (1,2,3,7,8-P5CDD)
mouse: oral LD50: > 5 mg/kg (1,2,4,7,8-P5CDD)
guinea pig: oral LD50: < 0.5 mg/kg

Toxic Equivalent Factor of 0.1 relative to 2,3,7,8 T_4CDD

heptachlorodibenzo-p-dioxins 37871-004

guinea pig: unreported route: LD50: > 0.6 mg/kg
Toxic Equivalent Factor of 0.01 relative to 2,3,7,8 T_4CDD

tetrachlorodibenzo-p-dioxins (mixed isomers)

Toxic Equivalent Factor of 0.01 relative to 2,3,7,8 T_4CDD

2,3,7,8-tetrachlorodibenzofuran 51207-31-9

guinea pig: LD50 0.005-0.01 mg/kg
monkey: intravenous: single dose: 30.7 ug/kg skin abnormalities
monkey: oral: single dose: 1 mg/kg: lethal 2/4 (24,31d)
monkey: oral: single dose: 1.5 mg/kg: lethal 4/4 (14,33d)
Toxic Equivalent Factor of 0.5 relative to 2,3,7,8 T_4CDD

hexachlorodibenzofurans (mixed isomers) 70648-26-9

H_6CDF isomers have been assigned a Toxic Equivalent Factor of 0.1 relative to 2,3,7,8 T_4CDD (MOE, 1986)

tetrachlorodibenzofurans (mixed isomers)

Toxic Equivalent Factor of 0.5 relative to the T_4CDFs.

Nonmammalian Summary:
Score: 10

2,3,7,8-tetrachlorodibenzo-p-dioxin 1746-01-6

Basis: Score based primarily on semi-chronic bird data and aquatic organisms:

bird: semi-chronic NOEL: 2.1 ug/kg(0.1 ug/kg/d)
bird: visible effects at 1.0 ug/kg/d
Mosquito larvae: NOAEL: > 0.0002 mg/l
Snail: NOAEL: > 0.002 mg/l
Daphnia: NOAEL: > 0.0013 mg/l

Polychlorinated Dibenzo-p-dioxins and -furans **n/a**

Mammalian Summary:
Score: 10

2,3,7,8-tetrachlorodibenzo-p-dioxin **1746-01-6**

Basis: Score based on chronic toxicity studies indicating most NOAELs at very low levels:
cattle, goats: oral: NOAEL: <0.004 mg/kg/d
rat: hepatocellular changes observed at the NOAEL for survival and tumor frequency of 0.001 ug/kg/d: 104wk
rat: 3 generation study: NOAEL: $1x10^{-6}$ mg/kg/d

pentachlorodibenzofuran **30402-15-4**

score based on a chronic, 13 wk oral study in rats. A LOAEL of 0.0001 mg/kg/d was divided by a factor of 10. Considerable supporting data exists:
rat, mouse: unr route: unr duration: AHH induction
rat: intravenous: hepatoma cells: AHH induction: EC50: 0.09-1.5 ug/plate
rat: subcutaneous: single dose: 0.37 mg/kg: inh. of weight gain, decreased locomotor activity, liver hypertrophy, thymus atrophy.
rat: oral: single dose: 0.1 - 2.0 mg/kg: dose dependent weight loss, piloerection, hair loss, hypoactivity, morbidity, death
rat: oral: 13 wk: 2, 20, 200 ug/kg diet (0.0001, 0.001. 0.01 mg/kg/d): decreased body/organ weight, decreased food consumption, severe liver lesions at 0.2 mg/kg; no effects except weak thymus atrophy at 0.002 mg/kg (0.0001 mg/kg/d): alterations in blood chemistry and hematology: 0.001 and 0.01 mg/kg/d (see CESARS for complete data set).

Teratogenicity:
Score: 10

2,3,7,8-tetrachlorodibenzo-p-dioxin **1746-01-6**

numerous studies indicate presentation of cleft palates, cardiovascular defects:
mouse (numerous studies): cleft palate, kidney abnormality: doses varied 1-400 ug/kg/d
mouse: NOAEL: teratogenic effects: 0.1 ug/kg/d
rat: NOAEL:(embryo/fetotoxic effects): 0.125 ug/kg/d
chick embryo: 0.003-25 ng/egg white on day zero: cardiovascular malformations: 30-80%.

Polychlorinated Dibenzo-p-dioxins and -furans n/a

hexachlorodibenzo-p-dioxins (mixed isomers) 34465-46-8

H_6CDDs considered teratogenic at doses of 0.001 to 0.01 mg/kg/d. The NOAEL for embryotoxicity and teratogenicity is 0.1 ug/kg/d.
rat: H_6CDD mixture: 1-10 ug/kg/d: subcutaneous oedema: 100 ug/kg/d: fetotoxic, fetal anomalies

pentachlorodibenzofuran 30402-15-4

score based on observations of cleft palate and hydronephrosis in mice at levels as low as 0.03 mg/kg/d in the absence of maternal toxicity:
mouse: unreported route: gestation day 10-13: hydronephrosis and cleft palate at doses not toxic to dams: 30-100 ug/kg/diet (0.03 - 0.1 mg/kg/d)
rat: oral (gavage): single dose: gestation day 8,10,12: 0.03 mg/kg fetotoxicity (high mortality); 0.03 mg/kg: decreased mean fetal weight; 0.03, 0.1, 0.3 mg/kg: cleft palates
mouse: oral (gavage): gestation day 10-13: hydronephrosis and cleft palate in the absence of an overt toxicity: 0-30 ug/kg.
mouse: oral (gavage): gestation day 10-13: no obvious maternal or fetal toxicity: cleft palate ED50: 0.036 mg/kg: hydronephrosis ED50: 0.007 mg/kg

Carcinogenicity:
Score: 8

2,3,7,8-tetrachlorodibenzo-p-dioxin 1746-01-6

Basis: IARC (Group 2B) sufficient evidence of carcinogenesis in experimental animals

Persistence:

Soil:

Score: 10

Basis: 45% remained 20 years after treatment (Prelim.,1991)
T 1/2 = 11 years after application of 50 mg/kg (Prelim.,1991)
T 1/2 = 11 years in sandy loam (Prelim.,1991)
T 1/2 = 14 years in sandy loam after initial application of 100 mg/kg (Prelim.,1991)
In unsterilized flooded soils T 1/2 for anaerobic biotransformation = 6 weeks (Prelim.,1991)

Water:

Score: 10

Basis: T1/2 for hydrolysis = 10 years (Prelim.,1991)
T 1/2 = 9 - 10 years (Prelim.,1991)

Sediment:

Score: 4Q

Basis: In unsterile sediment amended with organic matter T 1/2 for transformation = 1 week (Prelim.,1991)
In unsterilized flooded soils T 1/2 for anaerobic biotransformation = 6 weeks (Prelim.,1991)

Air:

Score: 4Q

Basis: T 1/2 for photolysis is greater than 10 years (Prelim.,1991)
T1/2 for degradation = 15 days (Prelim.,1991)
The residence time for toxaphene in air is 46-70 days (Prelim.,1991)

Bioaccumulation:

Score: 10

Basis: BCF: Brook Trout: 15d: 76000 (Prelim.,1991)
BCF: Catfish Fry: 91000 (Prelim.,1991)
BCF: Fathead minnow: 150d: 70000-107000 (Prelim.,1991)
BCF: Rainbow trout: 10000-20000 (Prelim.,1991)

Toxaphene **8001-35-2**

Toxicity:

Acute Aquatic:

Score: 10

Basis: Score based on 96h LC50 values in freshwater fish as low as 7.0 E-04 mg/l for the bluegill. Numerous other studies support this score (Prelim., 1991):

black bullhead: 96h LC50: 5.0 E-03 to 5.8 E-03 mg/l
brown trout: 96h LC50: 3.0 E-03 mg/l
coho salmon: 96h LC50: 8.0 E-03 mg/l
fathead minnow: 96h LC50: 0.018 mg/l

Persistence:

Soil:

Score: 10

Basis:* $T_{\frac{1}{2}}$ for nonsterile moist aerobic soil = 15 to 20 weeks (Prelim.,1989)

Water:

Score: 7

Basis: estuarine river (along Georgia coast): $T_{\frac{1}{2}}$ = 3-13 days (Prelim.,1989)
$T_{\frac{1}{2}}$ under optimal conditions = 1 to 3 weeks, under anaerobic conditions $T_{\frac{1}{2}}$ is several years (Prelim.,1989)
* $T_{\frac{1}{2}}$ is greater than 89 days in distilled water with an initial concentration of 0.7 mg/L Sn (Prelim.,1989)
$T_{\frac{1}{2}}$ = 18 days in distilled water with an initial concentration of 2-4 mg/L (Prelim.,1989)
* $T_{\frac{1}{2}}$ for freshwater = 3 to 89 days (Prelim.,1989)

Sediment:

Score: 10

Basis:* $T_{\frac{1}{2}}$ for submerged anaerobic soils is greater than 200 days (Prelim.,1989)

Air:

Score: *

Basis:

Bioaccumulation:

Score: 7

Basis: * BCF Carp: 7d: vertebra: 500 (Prelim.,1989)
* BCF Carp: 7d: muscle: 630 (Prelim.,1989)
* BCF Carp: 7d: kidney: 3160 (Prelim.,1989)
* BCF Carp: 7d: Liver: 5020 (Prelim.,1989)
BCF Goldfish 14d: 257 (OMOE,1991b)

Tributyl Tin **688-73-3**

Toxicity:

Acute Aquatic:
Score: 10

Basis: Score supported by by a multitude of fish species 96 h LC50s ranging from 0.00005 to 0.01 mg/l.

Nonmammalian Aquatic:
Score: 10

Basis: Score based on a multitude of species/studies showing longterm growth and developmental effects at <0.0002 mg/l.

Aquatic Phytotoxicity:
Score: 10

Basis: EC50s for algae ranged from 0.00033 to 0.016; growth of duckweed was reduced at 0.03 mg/l.

Part II: "Group A" Substances on the Secondary List

Benzo(b)fluoranthene **205-99-2**

Persistence:

Soil:
Score: 10L

Basis:* $T_{\frac{1}{2}}$ = 1 to 1.67 years based upon aerobic soil die-away test (SRC,1989)

Water:
Score: 4E

Basis:* $T_{\frac{1}{2}}$ = 8.7 hours to 30 days based upon estimated aqueous photolytic half life (SRC,1989)
Dissolved portion may undergo rapid photolysis (Prelim.,1987)
Biodegradation principal fate (Prelim.,1987)

Sediment:
Score: 10E

Basis:* based on analogy to other PAHs it is assumed to have a similar biodegradation half life in sediment ($T_{\frac{1}{2}}$ > 7000 hours), for clean sediment 10 to 400 times longer (Prelim.,1987)

Air:
Score: 0E

Basis:* $T_{\frac{1}{2}}$ = 1.43 to 14.3 hours based upon estimated photooxidation half life (SRC,1989)

Bioaccumulation:
Score: 7L

Basis:* BCF Daphnia magna: 10000 (Ma et al.,1990)
Log BCF: 5.15 (estimated) (Ma et al.,1990)
Log Kow: 6.57 (Ma et al.,1990)
Log Kow: 5.78 (Ma et al.,1990)

Toxicity:

Carcinogenicity:
Score: 10

Basis: IARC (listed Group 2B) sufficient evidence of carcinogenicity to animals:

rat: implant: respiratory system: ETA
mouse: skin: carcinogenic: positive
mouse: subcutaneous: ETA

Benzo(e)pyrene **192-97-2**

Persistence:

Soil:
Score: *

Water:
Score: *

Sediment:
Score: 10E

Basis:* based on analogy to other PAHs it is assumed to have a similar biodegradation half life in sediment ($T_{\frac{1}{2}}$ > 7000 hours), for clean sediment 10 to 400 times longer (Prelim.,1987)

Air:
Score: *

Bioaccumulation:

Score: 10L

Basis: * Log BCF Daphnia magna (24h): 4.4014 (25200) (Newsted et al., 1987)

Toxicity:

Acute Aquatic:
Score: 10Q

Basis: Score based on acute toxicity to Daphnia sp.. A Q tag was assigned due to questionable data (see anthracene):

Daphnia sp.: UV-LT50: 15.26h: 0.001 mg/l

Benzo(j)fluoranthene 205-82-3

Persistence:

Soil:
Score: *

Water:
Score: *

Sediment:
Score: 10E

Basis:* based on analogy to other PAHs it is assumed to have a similar biodegradation half life in sediment ($T_{\frac{1}{2}}$ > 7000 hours), for clean sediment 10 to 400 times longer (Prelim.,1987)

Air:
Score: *

Bioaccumulation:
Score: 10L

Basis:* Log Kow: 6.2 (Ma et al.,1990)

Toxicity:

Carcinogenicity:

IARC (listed GRP 2B) has determined that there is sufficient evidence that the compound is carcinogenic to experimental animals through several routes of exposure.

Benzo(k)fluoranthene **207-08-9**

Persistence:

Soil:
score: 10L

Basis: T 1/2 of 2.49-5.86 years based upon aerobic soil die-away test (SRC,1989)

Water:
Score: 4L

Basis:* T 1/2 of 3.8-499 hours based upon photolysis half life in water (SRC,1989)

Sediment:
Score: 10E

Basis:* based on analogy to other PAHs it is assumed to have a similar biodegradation half life in sediment ($T_{\frac{1}{2}}$ > 7000 hours), for clean sediment 10 to 400 times longer (Prelim.,1987)

Air:
Score: 0E

Basis:* Scientific judgement based upon estimated photooxidation half life of 1.1-11.0 hours in air (SRC,1989)

Bioaccumulation:
Score: 7L

Basis:* Log BCF Daphnia magna (24h): 13225 (Newsted et al., 1987)
Log Kow: 6.06 (Ma et al.,1990)
Log Kow: 6.84 (Ma et al.,1990)

Toxicity:

Acute Aquatic:
Score: 10Q

Basis: Score based on acute toxicity to Daphnia sp.. A Q tag was assigned due to use of questionable data (see anthracene):

Daphnia sp.: UV-LT50: 13h: 0.001 mg/l

Carcinogenicity:

IARC (listed Group 2B) has determined that there is sufficient evidence of carcinogenicity to experimental animals through several routes of exposure.

Beryllium 7440-41-7

Persistence:

Soil:
Score: 10

Basis: Beryllium is an element

Water:
Score: 10

Basis: Beryllium is an element

Sediment:
Score: 10

Basis: Beryllium is an element

Air:
Score: 10

Basis: Beryllium is an element

Bioaccumulation:
Score: 4Q

Basis:* Bioconcentration in the order of 20 times in fish (OMOE,1987)

Toxicity:

Acute Aquatic:
Score: CMR 7

Basis: Score based on acute 96 h TLm values to fish:
minnows: 96 h TLm: $BeSO_4$: 0.2 mg/l
minnows: 96 h TLm: $BeCl_2$ 0.15 mg/l
minnows: 96 h TLm: $Be(NO_3)_2$: 0.15 mg/l
Bluegill: 96 h TLm: $BeSO_4$: 1.3 mg/l

Carcinogenicity:

IARC (Group 2A) probable human carcinogen:

rat: inhalation: $BeSO_4$: 36 ug/m^3: 35h/wk/3-18mos: 3mos: pulmonary carcinomas in 19/22
rat: inhalation: $BeSO_4$: 33ug/m^3: 33-38h/wk: 1yr: pulmonary carcinomas in 4/8
rat: inhalation: Be oxide: 9 mg/m^3: 3-12mos: 22/36 lung tumours
rat: oral: $BeSO_4$: 5,50,500 ppm (diet): 2 years: increased lung reticulum cell carcinomas at 5,50 ppm
rabbit: intrvenous: unreported dose/duration: osteogenic sarcomas
rat: oral (drinking water): 5ppm: $BeSO_4$: long-term (unreported duration): negative

Bis(2-ethylhexyl) phthalate **117-81-7**

Persistence:

Soil:
Score: 4E

Basis:* $T_{\frac{1}{2}}$ = 5 to 23 days based upon unacclimated aqueous aerobic biodegradation (SRC,1989)
may biodegrade in soil under aerobic conditions following acclimation (Howard,1989)

Water:
Score: 4

Basis:* $T_{\frac{1}{2}}$ = 5 to 23 days based upon unacclimated aqueous aerobic biodegradation (SRC,1989)
* will biodegrade fairly rapidly $T_{\frac{1}{2}}$ = 2 to 3 weeks after acclimation (Howard,1989)
evaporation and hydrolysis not expected (Howard,1989)
* 56% degraded in 4 weeks in river water (Prelim.,1987)

Sediment:
Score: *

Basis: will strongly adsorb to sediments (Howard,1989)

Air:
Score: 0E

Basis:* $T_{\frac{1}{2}}$ estimated for photooxidation = 2.9 to 29 hours (SRC,1989)
washout by rain appears to be a significant process (Howard,1989)
will be carried long distances in the troposphere (Howard, 1989)

Bioaccumulation:
Score: 7

Basis:* BCF Fathead minnow: 155 to 886 (CMR,1982)
Log BCF Bluegill: 2.06 (115) (Howard,1989)
BCF Water flea: 5200 (CMR,1982)
Log Kow: 5.11 (Howard,1989)

Bis(2-ethylhexyl) phthalate **117-81-7**

Toxicity:

Nonmammalian Aquatic:
Score: 8Q

Basis: Score based on a 60% impairment of *Daphnia* sp. reproduction at 0.003 mg/l for a 21d test. This is an assumed LOAEL, hence the NOAEL (0.0003 mg/l) is obtained by dividing the LOAEL by a factor of 10:

Rainbow trout: NOEC(mortality, protein concentration): 90d: 0.005 mg/l
Fathead minnow: NOEC: 56d: 0.062 mg/l
Daphnia sp.: NOEC: 21d: 0.100 mg/l
Midge larvae: NOEC: 30d: 0.18 mg/l
Daphnia sp.: impaired reproduction by 60 %: 21d: 3 ug/l
Midge (*Chironomus tentans*): emergence significantly reduced at 0.014 mg/l
Midge (*Chironomus plumosus*): complete life cycle: 0.36 mg/l: no effects on adult emergence or egg hatchability.

Carcinogenicity:
Score: 8

Basis: Score supported by considerable carcinogenic and mutagenic data (see CESARS), positive results in transformation and promotion studies, and the IARC Group 2B rating.

Cadmium **7440-43-9**

Persistence:

Soil:
Score: 10

Basis: Cadmium is an element

Water:
Score: 10

Basis: Cadmium is an element

Sediment:
Score: 10

Basis: Cadmium is an element

Air:
Score: 10

Basis: Cadmium is an element

Bioaccumulation:
Score: 0

Basis:* BCF Bass: 8-15 (OMOE,1979)
* BCF Bluegill: 6-20 (OMOE,1979)
Numerous studies indicate accumulation, however bioconcentration factors are not given
BCF generally less than 100 (OMOE,1990d)
* The whole body BCFs for food exposed Rainbow trout and Whitefish were less than 1 (OMOE,1990d)

Toxicity:

Acute Aquatic:
Score: 10

Basis: Score based on high aquatic toxicity:

Rainbow trout:48 h LC50: 0.09 mg/l
Striped bass: 96 h LC50: 0.001 mg/l
Daphnia sp.: 48 h EC50: 0.03 mg/l
Daphnia sp.: 64 h EC50: <0.0026 mg/l
American lobster: 96 h LC50: 0.078 mg/l

Aquatic Phytotoxicity:
Score: 10L

Basis: Supported by one study indicating >0.001 ug/l Cd stopped growth and micronutrient utilization in FW diatoms within 20-30 hours.

Cadmium **7440-43-9**

Carcinogenicity:

IARC Group 2A indicating limited evidence of carcinogenicity in humans but sufficient evidence of carcinogenicity to experimental animals. Animal studies indicate subcutaneous injections can cause local sarcomas in rats whereas intramuscular injections of cadmium powder and cadmium sulphide can produce local tumors. Human studies indicate occupational exposure to cadmium (dust and fumes) increases the risk of prostate cancer in man and the incidence of respiratory tract cancers.

Chloroform **67-66-3**

Persistence:

Soil:
Score: 10E

Basis:* $T_{\frac{1}{2}}$ = 4 weeks to 6 months based on estimated aqueous aerobic biodegradation (SRC,1989)
chloroform will evaporate from near surface soil (Howard,1990)
* it can leach into groundwater and is subject to slow biodegradation (Howard,1990)

Water:
Score: 0

Basis:* Primarily lost to evaporation. Lab experiments have measured the half life for evaporation to be several hours and modelling studies suggest that the volatilization half life is 36 hours in a river, 40 hours in a pond and 9 to 10 days in a lake (Howard,1990)
$T_{\frac{1}{2}}$ = 4 weeks to 6 months based on estimated aqueous aerobic biodegradation (SRC,1989)

Sediment:
Score: *

Air:
Score: 7

Basis:* Chloroform will degrade by reactions with hydroxyl radicals, half life = 80 days (Howard,1990)
It may be transported long distances and will partially return to earth in precipitation (Howard,1990)
* $T_{\frac{1}{2}}$ = 26 to 260 days based upon photooxidation (SRC,1989)

Bioaccumulation:
Score: 0

Basis:* BCF Bluegill: 6, 1.6-2.5 (Howard,1990)
* BCF Rainbow trout: 3.34-10.35 (Howard,1990)
* BCF Largemouth bass: 2.9-3.1 (Howard,1990)
* BCF Channel catfish: 3.3-3.7 (Howard,1990)
Log Kow: 1.97 (Howard,1990)

Chloroform 67-66-3

Toxicity:

Carcinogenicity:

Score: 10

Basis: Score based on positive results in long term cancer studies (several routes of exposure), positive evidence of direct interaction with genetic material, and conclusions of RTECS, EPA, and IARC (GRP 2B) indicating sufficient evidence for carcinogenicity to animals. See preliminary assessment for complete data set.

Chromium (Cr^{+6}) 7440-47-3

Persistence:

Soil:
Score: 10

Basis: Chromium is an element

Water:
Score: 10

Basis: Chromium is an element

Sediment:
Score: 10

Basis: Chromium is an element

Air:
Score: 10

Basis: Chromium is an element

Bioaccumulation:
Score: 0Q

Basis: homeostatically regulated by fish, rather than partitioning based on their lipophillic nature (CESARS,1990)
* Chromium does not accumulate within freshwater organisms to any great extent (OMOE,1987)

Toxicity:

Carcinogenicity:

Basis: IARC (Group 1) sufficient evidence for carcinogenicity to mice and rats and sufficient evidence of respiratory carcinogenesis in men occupationally exposed to chromate production. See CESARS for considerable supporting data.
rat: inhalation: 0.100 mg/m^3 cont. for 18months: weak carcinogen: lung tumours
rat: implant: unreported dose: calcium chromate: 136 weeks: lung sarcomas, adenosarcomas
rat: implant: 12.5 mg/month for 2 yrs: calcium chromate: local tumours: chromic acetate: sarcomas
human: inhalation: occupationally exposed: significantly higher incidence of tracheal, bronchial, lung cancers

Chrysene 218-01-9

Persistence:

Soil:

Score: 10L

Basis:* $T_{\frac{1}{2}}$ of of 1.02-2.72 years based upon aerobic soil die-away test (SRC,1989)

Water:

Score: 7L

Basis: Scientific judgement based upon sunlight photolysis half-life in water of 4.4-13 hours (SRC,1989)
T 1/2 of 13 days for photolysis in water (Ma et al.,1990)
* Direct photolysis in a 5 meter deep inland water body with partitioning to sediment, T 1/2 = 68 days, T 1/2 without partitioning = 13 days (Zepp et al., 1979)

Sediment:

Score: 10E

Basis:* Based on analogy to other PAHs with 4 or more rings which biodegrade slowly in contaminated sediments ($T_{\frac{1}{2}}$ > 7000 hours), in clean sediments 10 to 400 times longer (Prelim.,1987)

Air:

Score: 0E

Basis:* T 1/2 = 0.802 to 8.02 hours based upon estimated photooxidation half-life in air (SRC,1989)

Bioaccumulation:

Score: 7L

Basis:* Log BCF Daphnia magna (24h): 3.7845 (6088) (Newsted et al.,1979)
Log Kow: 5.61 (Ma et al.,1990)
Log Kow: 5.79 (Ma et al.,1990)
Log Kow: 5.91 (Ma et al.,1990)

Toxicity:

Acute Aquatic:

Score: 10Q

Basis: Score based on photo-induced toxicity of chrysene to Daphnia sp.. See anthracene re: Q tag.

Daphnia sp.: UV-LT50: 23.98h: 0.002 mg/l

Copper 7440-50-8

Persistence:

Soil:
Score: 10

Basis: Copper is an element

Water:
Score: 10

Basis: Copper is an element

Sediment:
Score: 10

Basis: Copper is an element

Air:
Score: 10

Basis: Copper is an element

Bioaccumulation:
Score: 4

Basis:* BCF Fathead minnow: 30d: 290 (Prelim.,1990)

Toxicity:

Acute Aquatic:
Score: 10

Basis: Score supported by aquatic toxicity data, in particular *Daphnia* sp. and mayfly LC50s of the order of 0.005 mg/l. Other aquatic studies for fish also strongly support score. See CESARS for complete data set:

Daphnia sp.: LC50: 48h: 0.0056 mg/l
Salmonids/Bluegills: LC50: 96h: 0.03 - 6.0 mg/l
Fathead minnow: LC50: 96h: 0.250 mg/l: 28d: 0.123 mg/l
Trout: LC50: 10d: 0.05 mg/l
Chinook salmon: LC50: 96h: 0.010 mg/l
Trout: $CuCl_2$: LC50: 96h: 0.0157 mg/l

Copper **7440-50-8**

Nonmammalian Aquatic:

Score: 10

Basis: Score based on several aquatic species (amphipods, Daphnia sp., trout) with reported chronic toxicity less than 0.02 mg/Cu/l (scored as EC50). See CESARS for complete data set:

several aquatic sp.:NOAEL: 0.005 - 0.015 mg Cu/l
Chinook salmon: $CuCl_2$: early life stage tests: < 0.0074 mg Cu/l: adverse effects
Brook trout: $CuSO_4$: early life stage tests (physiological effects): 0.003 - 0.005 mg Cu/l
Fathead minnow: MATC (growth, reproduction): unreported duration: 0.011 - 0.018 mg Cu/l

Aquatic Phytotoxicity:

Score: 10

Basis: Score based on complete growth inhibition of diatoms at 0.005 mg/l and numerous studies indicating copper is toxic to algae (reduced photosynthesis, growth inhibition) in the range of 0.001 to 0.10 mg/l. See CESARS for complete data set.

Dibenz(a,h)acridine **226-36-8**

Persistence:

Soil:
Score: *

Water:
Score: *

Sediment:
Score: 10E

Basis: Based on analogy to other PAHs with 4 or more rings which biodegrade slowly in contaminated sediments ($T_{\frac{1}{2}}$ > 7000 hours), in clean sediments 10 to 400 times longer (Prelim.,1987)

Air:
Score: *

Bioaccumulation:
Score: 7Q

Basis:* BCF Fathead minnow: 100 (not confirmed) (Prelim.,1987)
* Log Kow: 4.02 (Prelim.,1987)

Toxicity:

Carcinogenicity:
Score: 10L

Basis: Score based on numerous mouse studies employing oral, dermal, subcutaneous, and intravenous routes of administration. See CESARS for complete data set. "L" designation due to mouse only data.
IARC (listed Group 2B) sufficient evidence for carcinogenicity to animals.

Dibenz(a,j)acridine **224-42-0**

Persistence:

Soil:
Score: *

Water:
Score: *

Sediment:
Score: 10E

Basis:* Based on analogy to other PAHs with 4 or more rings which biodegrade slowly in sediments ($T_{\frac{1}{2}}$ > 7000 hours), 10 to 400 times longer in clean sediments (Prelim.,1987)

Air:
Score: *

Bioaccumulation:
Score: 7E

Basis: based on analogy to other PAHs with 4 or more rings which have a Log Kow > 4 (Prelim.,1987)

Toxicity:

Carcinogenicity:
Score: 10L

Basis: Score based on mouse dermal and subcutaneous studies. "L" designation due to only mouse data available. IARC (listed Group 2B) sufficient evidence for carcinogenicity to experimental animals.

Dibenzo(a,i)pyrene **189-55-9**

Persistence:

Soil:
Score: 10L

Basis:* $T_{\frac{1}{2}}$ = 232 to 361 days based upon aerobic soil die-away test (SRC,1989)

Water:
Score: 10E

Basis:* $T_{\frac{1}{2}}$ = 2.54 to 3.96 years based upon estimated unacclimated aqueous aerobic biodegradation (SRC,1989)

Sediment:
Score: 10E

Basis:* based on analogy to other PAHs it is assumed to have a similar biodegradation half life in sediment ($T_{\frac{1}{2}}$ > 7000 hours), for clean sediment 10 to 400 times longer (Prelim.,1987)

Air:
Score: 0E

Basis:* $T_{\frac{1}{2}}$ = 0.321-3.21 hours based upon estimated photooxidation half life (SRC,1989)

Bioaccumulation:
Score: 10L

Basis:* Log Kow 7.29 (CIS,1991)

Toxicity:

Carcinogenicity:
Score: 10

Basis: IARC sufficient evidence (Group 2B) for carcinogenicity to animals including:

mouse: subcutaneous: Lowest published toxicity dose: 1 mg/kg : ETA
mouse: skin: Lowest published toxicity dose: 47 mg/kg/39 wks
mouse: subcutaneous/intramuscular: sarcomas 33/35
hamster: intratracheal: 33g/kg/8 wks -intermittent
hamster: subcutaneous: Lowest published toxicity dose: 2 mg/kg: neoplastic effects

7H-Dibenzo(c,g)carbazole **194-59-2**

Persistence:

Soil:
Score: *

Water:
Score: *

Sediment:
Score: 10E

Basis:* Based on analogy to other PAHs with 4 or more rings which biodegrade slowly in contaminated sediments ($T_{\frac{1}{2}}$ > 7000 hours), in clean sediments 10 to 400 times longer (Prelim.,1987)

Air:
Score: *

Bioaccumulation:
Score: 7E

Basis: based on analogy to other PAHs with 4 or more rings which have a Log Kow > 4 (Prelim.,1987)

Toxicity:

Carcinogenicity:
Score: 10

Basis: IARC (listed Group 2B) sufficient evidence of carcinogenicity to experimental animals. Compound has produced cancers in animals (papillomas, carcinomas, hepatomas, pulmonary adenomas, sarcomas, tumors) in many test systems with various exposure routes/ dosages/durations.

7,12-Dimethylbenz(a)anthracene **57-97-6**

Persistence:

Soil:

Score: 4

Basis:* $T_{\frac{1}{2}}$ = 20 to 28 days based upon aerobic soil die-away test (SRC,1989)
Will remain in surface layers due to strong adsorption (Prelim., 1989)

Water:

Score: 4E

Basis:* $T_{\frac{1}{2}}$ for volatilization is estimated to be 20 days from a typical river (Prelim.,1989)
Estimated half life for the dissolved compound in natural waters from the southeastern U.S. is 6 hours. (Prelim.,1989)

Sediment:

Score: 10E

Basis: DMBA released into water will adsorb to sediment and particulate matter in the water column (Prelim.,1989)
* Based on analogy to other PAHs with 4 or more rings which biodegrade slowly in sediments ($T_{\frac{1}{2}}$ > 7000 hours), 10 to 400 times longer in clean sediments (Prelim.,1987)

Air:

Score: 0E

Basis:* 7,12-DMBA will photodegrade readily in the atmosphere by reactions with ozone, oxidants, nitrogen oxides and sulphur oxides (Prelim.,1989)
* $T_{\frac{1}{2}}$ 0.32 to 3.2 hours based upon estimated photooxidation half life (SRC,1989)
Will exist in free vapour state and adsorbed to particulate matter (Prelim.,1989)

Bioaccumulation:

Score: 10L

Basis:* Log Kow: 6.94 (Prelim.,1989)
Log Kow: 5.65 (Prelim.,1989)

7,12-Dimethylbenz(a)anthracene **57-97-6**

Toxicity:

Acute Aquatic:

Score: 10E

Basis: Score based on estimated (QSAR) 96h LC50 in Fathead minnows of 0.0029 mg/l

Carcinogenicity:

Score: 10

Basis: Positive evidence of carcinogenicity in many animal species by many routes of exposure and evidence of interaction with DNA (see Mutagenicity). See CESARS for extensive data set.

1,8-Dinitropyrene **42397-65-9**

Persistence:

Soil:
Score: *

Water:
Score: *

Sediment:
Score: 10E

Basis:* based on analogy to other PAHs with more then 4 rings which will slowly biodegrade in contaminated sediment ($T_{\frac{1}{2}}$ > 7000 hours), in clean sediments 10 to 400 times longer (Prelim.,1987)

Air:
Score: *

Bioaccumulation:
Score: 7E

Basis:* based on analogy to other PAHs with 4 or more rings which have Log Kow values > 4 (Prelim.,1987)

Toxicity:

Carcinogenicity:
Score: 10

Basis: IARC (listed GRP 2A) probable human carcinogen bioassay data available for 2 species with evidence of direct interaction with genetic material:

hamster: embryo: ocogenic transformation: 1700 nmol/l
rat: subcutaneous: 10 wk- intermittent: Lowest published toxic dose: 16 mg/kg: local tumors.

1,4-Dioxane 123-91-1

Persistence:

Soil:

Score: 10E

Basis: should volatilize from dry soil based on its moderate vapour pressure (Prelim.,1990)
leaching is expected based on its infinite water solubility and low estimated soil adsorption coefficient (Prelim.,1990)
aerobic degradation, 28°C: West Valley NY soil sample: 0, 10% degradation: unr duration: N addition increased degradation (Prelim.,1990)
* $T_{\frac{1}{2}}$ estimated for unacclimated aqueous aerobic biodegradation = 4 weeks to 6 months (SRC,1989)

Water:

Score: 10

Basis: * $T_{\frac{1}{2}}$ estimated for unacclimated aqueous aerobic biodegradation = 4 weeks to 6 months (SRC,1989)
Not expected to hydrolyze significantly (Howard,1990)
* 1,4-Dioxane exhibited a negligable biological oxygen demand in two activated sludge experiments and the compound has been classified as relatively undegradable (Howard,1990)
* Photooxidation by reaction with aqueous hydroxyl radicals: pH 7: room temperature: $T_{\frac{1}{2}}$ = 336 days (Prelim.,1990)
* Oxidation reaction with RO2: $T_{\frac{1}{2}}$: 1729 years at 30°C (Prelim.,1990)
Volatilization half life cannot be determined due to its infinite solubility in water, however volatilization may be significant due to its moderate vapour pressure (Prelim.,1990)

Sediment:

Score: *

Basis: It is not expected to significantly adsorb to suspended sediments (Howard,1990)

Air:

Score: 0E

Basis:* $T_{\frac{1}{2}}$ based upon estimated photooxidation half life in air = 0.34 to 3.4 days (SRC,1989)

* The half life of the reaction of 1,4-Dioxane with photochemically produced hydroxyl radicals in the atmosphere is estimated to be 6.69 to 9.6 hours (Howard,1990)

Bioaccumulation:

Score: 0E

Basis: not expected to bioconcentrate (Howard,1990)

* Log Kow: -0.27 (measured) (Howard,1990)
* Log Kow: -0.42 (Prelim.,1990)

Toxicity:

Carcinogenicity:

Score: 10

Basis: Score based on sufficient evidence of carcinogenicity in mice and rats, some evidence of genotoxicity, and the IARC (Group 2B), RTECS, and EPA conclusions of sufficient evidence of carcinogenicity to animals. See CESARS for complete data set.

IARC (1976) reports 1,4 dioxane is carcinogenic in rats and guinea pigs by oral administration: it produces malignant tumours of the nasal cavity and liver in rats and tumours of the liver and gall bladder in guinea pigs.

1,2-Diphenylhydrazine **122-66-7**

Persistence:

Soil:

Score: 10E

Basis:* $T_{\frac{1}{2}}$ based upon estimated aqueous aerobic biodegradation = 4 weeks to 6 months (SRC,1989)
Soil, sediment, particulate matter: adsorption: moderate and may increase with oxidation rate by facilitating contact with environmentally prevalent cations which catalyze its oxidation (Prelim.,1990)

Water:

Score: 0

Basis:* biodegradation of 5 and 10 mg/L had 80 and 72% degraded at 7 days (Prelim.,1988)
* Oxidation to azobenzene: aerobic conditions: $T_{\frac{1}{2}}$: catalyzed by cations such as Cu(II) 1.16 minutes and uncatalyzed 5.78 minutes (Prelim.,1990)
* Biodegradation, aerobic screening test 1.3% BODT: 6d, 1 acclimation day, (acclimated to aniline), innoculum-activated sludge (Prelim.,1990)
* $T_{\frac{1}{2}}$ = 1.3 to 72 days based upon photooxidation rate constants with OH and RO_2 for the aromatic amine class, it is assumed that hydrazobenzene reacts twice as fast (SRC,1989)

Sediment:

Score: *

Basis: Soil, sediment, particulate matter: adsorption: moderate and may increase with oxidation rate by facilitating contact with environmentally prevalent cations which catalyze its oxidation (Prelim.,1990)

Air:

Score: 0

Basis:* autooxidizes in air, $T_{\frac{1}{2}}$ for oxidation = a few minutes (Prelim.,1988)
* $T_{\frac{1}{2}}$ oxidation (catalyzed) = 5.78 minutes, (Uncatalyzed) = 5.78 minutes (Prelim.,1988)
* $T_{\frac{1}{2}}$ estimated for photooxidation half life = 18 minutes to 3.0 hours (SRC,1989)

1,2-Diphenylhydrazine **122-66-7**

Bioaccumulation:
Score: 4L

Basis:* Log Kow: 2.94 (Prelim.,1988)

Toxicity:

Carcinogenicity:
Score: 10

Basis: Score based on clear evidence of carcinogenicity in mice and rats, and evidence of interaction with genetic material:

mouse (female): oral (diet): hepatocellular carcinomas, adenomas: TDLo 26 g/kg/78 wks: carcinogenic by RTECS criteria: clear evidence
rat: oral (diet): tumours of liver, adrenal gland, ear: Lowest published toxic concentration 2.62 g/kg/78 wks: carcinogenic by RTECS criteria: clear evidence
rat: subcutaneous: Lowest published toxic concentration 6000mg/kg/27wks: equivocal tumorigenic agent by RTECS criteria: skin, appendages, uterine tumours
mouse: skin: Lowest published toxic concentration 5280 mg/kg/26wks: equivocal tumorigenic agent by RTECS criteria: liver tumours
mouse, rat: EPA GENETOX Program 1988: positive

Ethylene Dibromide **106-93-4**

Persistence:

Soil:

Score: 7Q

Basis:
* no biodegradation under anaerobic conditions using nitrifying bacteria during an 8 week test (Prelim.,1990)
* degraded completely to ethylene in 2 months in soil culture (Prelim.,1990)
* leaches into groundwater where it is apparently persistent (Prelim.,1990)

97% biodegraded by soil microorganisms during a 4 week test using an initial concentration of 0.00058 M (Prelim.,1990)

Water:

Score: 0

Basis:
* hydrolysis half life under natural conditions at ambient temperatures = 5 to 10 days (Prelim.,1990)

Biodegradation may not be a significant fate process judging from the relatively slow biodegradation in soils (Prelim.,1990)
* $T_{\frac{1}{2}}$ for evaporation of a 1ppm stirred solution 1.6 cm deep = 6.8 minutes (Prelim.,1990)
* $T_{\frac{1}{2}}$ for evaporation with a wind velocity of 8.6 m/sec and a depth of 1 meter = 4.3 hours (Prelim.,1990)
* $T_{\frac{1}{2}}$ for volatilization from ambient surface water = 2 to 16 days depending on environment, based on EXAMS model (Prelim.,1990)
* $T_{\frac{1}{2}}$ estimated for a typical river and a typical lake = 32 hours and 130 hours respectively (Prelim.,1990)
* $T_{\frac{1}{2}}$ for estimated for evaporation from a river 1 meter deep with a wind velocity of 3 m/sec and a current velocity of 1 m/sec = 6.1 hours (Prelim.,1990)

Sediment:

Score: *

Air:

Score: 4E

Basis: atmospheric oxidation with peroxides and ozone $T_{\frac{1}{2}}$ > 100 days (Prelim.,1990)
* $T_{\frac{1}{2}}$ estimated for reaction with hydroxyl radicals ≈ 32 days, or a 2.2% loss per sunlit day (Prelim.,1990)

Ethylene Dibromide **106-93-4**

Bioaccumulation:
Score: 0L

Basis: Log Kow: 2.13 (Prelim.,1990)
* BCF fish: < 10 (Prelim.,1990)

Toxicity:

Carcinogenicity:
Score: 10

Basis: Score supported by conclusive evidence of carcinogenesis in mice and rats by multiple routes, evidence of direct interaction with DNA, and the IARC (Group 2A) designation indicating this compound is a probable human carcinogen (see CESARS for complete data set)

Hexachlorocyclopentadiene 77-47-4

Persistence:

Soil:

Score: 0

Basis: biodegradation rapid under aerobic and anaerobic conditions (Prelim.,1990)
In nonsterile soil 6.1% was recovered as nonpolar material (Prelim.,1990)
63.6% degraded in 14 days including volatilization (Prelim.,1990)
23 organisms were tested for their ability to biodegrade hexachlorocyclopentadiene. Of the 23, 7 had more than 33% degraded within 14 days (Prelim.,1990)
* greater than 90% degrades in approximately 7 days (Prelim.,1990)
* $T_{\frac{1}{2}}$ = 7 days to 4 weeks based upon aqueous aerobic biodegradation (SRC,1989)

Water:

Score: 0

Basis:* Irradtion with a mercury vapour lamp yielded a photolysis half life of 1.03 minutes and 100% was degreded in 10 minutes (Prelim.,1990)
* The photlytic half life in distilled water is 4 minutes (Prelim.,1990)
* The photlytic half life in black, turbid water is less than 10 minutes (Prelim.,1990)
The hydrolysis half life in the pH range 5-9 is 14 days (Prelim.,1990)
The hydrolysis half life at pH 6 is 14 days (Prelim.,1990)
The hydrolytic half life at 25°C at pH 6 and in the dark is 11.4 days (Prelim.,1990)
100% biodegradation occured in 7 days in a wastewater test (Prelim.,1990)
* $T_{\frac{1}{2}}$ = 1.0 minute based upon photolysis (SRC,1989)
* $T_{\frac{1}{2}}$ = 7.2 days based upon hydrolysis (SRC,1989)

Sediment:

Score: *

Basis:

Hexachlorocyclopentadiene **77-47-4**

Air:

Score: 0E

Basis:* Atmospheric residence time was estimated based upon the reaction with hydroxyl radicals is 5 hours (Prelim.,1990)
* $T_{\frac{1}{2}}$ = 1.0 to 8.9 hours based upon estimated photooxidation half life in air (SRC,1989)

Bioaccumulation:

Score: 7

Basis: BCF Fathead minnow 30d: < 11 (Prelim.,1990)
BCF Fathead minnow 32d: 29 (Prelim.,1990)
BCF Fathead minnow: 11 (Prelim.,1990)
BCF Fathead minnow: 30 (Prelim.,1990)
BCF Goldfish: 468 (Prelim.,1990)
* BCF Golden orfe: 1230 (Prelim.,1990)
BCF mosquito larvae: 7d: 929 (Prelim.,1990)
BCF fish: 448 (Prelim.,1990)
BCF Snails: <33d: 1634 (Prelim.,1990)
Log Kow: 4.28 (Prelim.,1990)
Log Kow: 2.74 (Prelim.,1990)
Log Kow: 5.51 (Prelim.,1990)
Log Kow: (est.): 5.51 (Prelim.,1990)
Log Kow: 5.04 (OMOE,1991)

Toxicity:

Acute Aquatic:

Score: 10

Basis: Score based on acute toxicity to a variety of aquatic invertebrate and invertebrate species:

Daphnia sp.: 48h LC50: 0.039, 0.052 mg/l
Fathead minnow: 96h LC50: 0.18 mg/l
Fathead minnow (larvae): 96h LC50: 0.007 mg/l
Goldfish: 96h LC50: 0.078 mg/l
Bluegill(0.45g): 96h LC50: 0.13 mg/l
Channel catfish: 96h LC50: 0.097 mg/l

Hexachlorocyclopentadiene 77-47-4

Mammalian Inhalation:

Score: 10

Basis: Score based on rat inhalation 210 day NOAEL of 0.009 ppm and numerous other studies with various species:

rat: inhalation: 210d: 0.009 ppm (0.1 mg/m^3) Time Weighted Average: NOEL: body/organ weight and histopathology: 0.018 ppm TWA: effect level: 0.089 ppm Time Weighted Average: adverse effect level.
rat: inhalation: 90d: 0.009 ppm (0.1 mg/m^3) Time Weighted Average: NOAEL: no measurable clinical or physical effects: 0.036 ppm TWA: effect level: marginal haematological and organ weight changes.
rat, guinea pig: inhalation: 42d: 0.069 ppm (0.77 mg/m^3) Time Weighted Average: adverse effect level: guinea pig survived 30 periods of exposure, lethal to rats before 20th exposure.
monkey: inhalation: 90d: 0.002 ppm (0.022 mg/m^3) Time Weighted Average: no treatment related abnormalities, organ weight, pathology or histopathology.(see CESARS)

Indeno(1,2,3-cd)pyrene **193-39-5**

Persistence:

Soil:
Score: 10L

Basis:* $T_{\frac{1}{2}}$ = 1.64 to 2 years based on aerobic soil die-away test (SRC,1989)

Water:
Score: 10E

Basis:* $T_{\frac{1}{2}}$ = 125 to 250 days based upon estimated aqueous photolysis half life in water (SRC,1989)

Sediment:
Score: 10E

Basis:* based on analogy to other PAHs it is assumed to have a similar biodegradation half life in sediment ($T_{\frac{1}{2}}$ > 7000 hours), for clean sediment 10 to 400 times longer (Prelim.,1987)

Air:
Score: 0E

Basis:* $T_{\frac{1}{2}}$ = 0.629 to 6.29 hours based upon estimated photooxidation half life in air (SRC,1989)

Bioaccumulation:
Score: 10L

Basis:* Log Kow: 7.66 (Prelim.,1987)
* Log Kow: 6.584 (CIS,1991)

Toxicity:

Carcinogenicity:
Score: 10

Basis: IARC (listed Group 2B) sufficient evidence of carcinogenicity to animals:

mouse: skin: 1 year: 0.1% sol.: 3x/wk: papllomas,sarcomas
mouse: skin: 10 paintings at 2 d intervals(total 250 ug):skin carcinomas
mouse: subcutaneous, intramuscular: 3 x 0.6 mg at 1 month intervals: sarcomas
mouse: subcutaneous: 9 wk - intermittent: 72 mg/kg: carcinogenic
rat: implant: Toxic Dose: 20.75 mg/kg: carcinogenic effects
rat: implant: Lowest published toxic dose: 4.15 mg/kg: carcinogenic effects
hamster: lung: oncogenic transformation: 100 ug/l

Persistence:

Soil:

Score: 10

Basis: Lead is an element

Water:

Score: 10

Basis: Lead is an element

Sediment:

Score: 10

Basis: Lead is an element

Air:

Score: 10

Basis: Lead is an element

Bioaccumulation:

Score: 4

Basis:* BCF Bluegill:(muscle): 45 (OMOE,1990b)
* BCF Brook Trout: (muscle): 42 (OMOE,1990b)
Almost three times as much lead was accumulated by freshwater fish at pH 6.0 as was accumulated at pH 7.5 (OMOE,1987)

Toxicity:

Carcinogenicity:

IARC (1982) designation as Group 2B, sufficient evidence of carcinogenicity to animals, insufficient evidence of carcinogenicity to humans. Lead salts have been shown to induce tumours at high doses (i.e.1000 ppm) in rats. Tumour development was accompanied by high blood lead levels and moderate to severe toxicological effects and significant levels of mortality. Renal tumours have been induced in rats and mice exposed to dietary lead acetate, and in rats fed lead subacetate or lead phosphate at approximately 50 mg/kg/day.

Pyrene **129-00-0**

Persistence:

Soil:

Score: 10L

Basis:* $T_{\frac{1}{2}}$ = 210 days to 5.2 years based upon aerobic soil die-away test at 10-30°C (SRC,1989)

Water:

Score: 0

Basis:* $T_{\frac{1}{2}}$ = 0.68 to 2.04 hours based upon estimated sunlight photolysis half life in water (SRC,1989)

* $T_{\frac{1}{2}}$ for direct photolysis in a 5 metre deep inland water body with no partitioning to sediment = 4.2 days; with partitioning to sediment = 5.9 days (Zepp et al., 1979)

Sediment:

Score: 10E

Basis:* based on analogy to other PAHs with 4 or more rings which biodegrade slowly in contaminated sediment ($T_{\frac{1}{2}}$ > 7000 hours), in clean sediment 10 to 400 times longer (Prelim.,1987)

Air:

Score: 0E

Basis:* $T_{\frac{1}{2}}$ = 0.68 to 2.04 hours based upon estimated sunlight photolysis half life in water (SRC,1989)

Bioaccumulation:

Score: 7L

Basis:* Log BCF Daphnia magna (24h): 3.4317 (2702) (Newsted, et al.,1987)
Log Kow:5.18 (Ma et al.,1990)
Log Kow:5.00 (Ma et al.,1990)
Log Kow:4.88 (Ma et al.,1990)
Log Kow:5.32 (Ma et al.,1990)
Log Kow:4.90 (Ma et al.,1990)
Log Kow:5.22 (Ma et al.,1990)

Pyrene 129-00-0

Toxicity:

Acute Aquatic:
Score: 10Q

Basis: Score based on acute toxicity to daphnia and mosquito larvae. Q tag assigned due to presence of questionable data (see anthracene):

Daphnia sp.: UV-LT50: 3.47h: 0.006 mg/l
Daphnia sp.: UV 1h LC50: 0.004 mg/l
Mosquito larvae: UV 1h LC50: 0.02 mg/l

Silver (free ion) **7440-22-4**

Persistence:

Soil:
Score: 10

Basis: Silver is an element

Water:
Score: 10

Basis: Silver is an element

Sediment:
Score: 10

Basis: Silver is an element

Air:
Score: 10

Basis: Silver is an element

Bioaccumulation:
Score: 4L

Basis:* BCF Fish: 15-240 (OMOE,1987)

Toxicity:

Acute Aquatic:
Score: CMR 7

Basis: Numerous studies have indicated LC50 values (≤ 96h) as 0.0049 to 0.0844 mg/l in fish while for invertebrates the range is 0.0006 to 4.5 mg/l.(U.S.EPA, 1980. Ambient Water Quality for Silver. Office of Water Regulations and Standards. Washington, D.C.)

Styrene 100-42-5

Persistence:

Soil:

Score: 7

Basis:* Styrene released to soils is subject to biodegradation. Degradation of 87-95% has been observed in sandy loam and landfill soil over a 16 week incubation and degradation of 2.3-12% per week has been observed with two subsurface aquifers (Howard,1989)

Styrene may exhibit low to moderate soil mobility depending on soil conditions (Howard,1989)

* Styrene which has leaked into soil from buried drums can persist for up to 2 years (Howard,1989)

$T_{\frac{1}{2}}$ = 2 to 4 weeks based upon unacclimated grab samples of aerobic soil and acclimated aqueous screening test data (SRC,1989)

Water:

Score: 0

Basis:* The volatilization half life of styrene from a river 1 meter deep with a current speed of 1 m/sec and a wind velocity of 3 m/sec is about 3 hours (Howard,1989)

Hydrolysis is not expected to be an important process (Howard,1989)

Adsorption to particulate matter and sediment may have some significance (Howard,1989)

$T_{\frac{1}{2}}$ = 2 to 4 weeks based upon estimated unacclimated aqueous aerobic screening test data (SRC,1989)

* Estimated half life for evaporation from a pond = 3 days and from an oligotrophic lake $T_{\frac{1}{2}}$ = 13 days (Prelim.,1990)

* Oxidation, 10, 15 and 20 days; 65,78 and 87% degradation respectively (Prelim.,1990)

* Overall half life of 0.6 days in a river suggesting a fairly rapid disappearance > 100 times faster than in groundwater (Prelim.,1990)

Sediment:

Score: *

Styrene **100-42-5**

Air:

Score: 0

Basis:* Styrene vapour in the atmosphere will react rapidly with hydroxyl radicals and ozone, with half lives calculated at 3.5 and 9 hours respectively (Howard,1989)
* $T_{\frac{1}{2}}$ = 51 minutes to 7.3 hours based upon measured rate data for the reaction with hydroxyl radicals (SRC,1989)
* Reactivity in a smog chamber with NO_x and natural sunlight found 55% disappearance in 2 hours (Prelim.,1990)

Bioaccumulation:

Score: 0

Basis:* BCF Goldfish: 13.5 (Howard,1989)
Log Kow: 2.95 (Howard,1989)

Toxicity:

Carcinogenicity:

Score: 10

Basis: Score based on IARC (Group 2B) designation of "limited" evidence of carcinogenicity to animals (mice and rats). IARC indicates sufficient evidence for carcinogenesis using styrene oxide, an *in vivo* metabolite of styrene. Q tag assigned because of some questionable data (rat).

Persistence:

Soil:

Score: 10E

Basis:* $T_{\frac{1}{2}}$ = 4 weeks to 6 months based upon estimated unacclimated aqueous aerobic biodegradation (SRC,1989)
Would adsorb fairly strongly under acidic conditions but expected to leach into ground (Prelim.,1987)

Water:

Score: 4E

Basis: would probably photolyze in surface waters and possibly biodegrade very slowly (Prelim.,1987)
* $T_{\frac{1}{2}}$ for photolysis estimated using data for 2,4,5-Trichlorophenol and pentachlorophenol, $T_{\frac{1}{2}}$ = 1 hour to 14 days (SRC,1989)

Sediment:

Score: *

Basis: Adsorbs to sediment and particulate matter in water column (Prelim.,1987)

Air:

Score: 10E

Basis:* $T_{\frac{1}{2}}$ = 15.2 to 151.9 days based upon estimated photooxidation half life in air (SRC,1989)
would photolyze with half life of somewhat longer than 1.5 days (Prelim.,1987)

Bioaccumulation:

Score: 4

Basis:* BCF Goldfish: 93 (Prelim.,1987)
* BCF Goldfish: 89 (Prelim.,1987)
* BCF Guppy: 200 (Prelim.,1987)
Log Kow: (range) 4.1 to 4.45 (Prelim.,1987)

Toxicity:

Carcinogenicity:

Score: 10L

Basis: Score based on limited direct evidence of carcinogenesis to animals. IARC has classified chlorophenols as Group 2B indicating there is sufficient evidence. Some evidence of carcinogenesis in mice by RTECS criteria.

Tetraethyl lead **78-00-2**

Persistence:

Summary score: 10

Basis:* based on the persistence of the metal component (Prelim.,1987)

Soil:

Score: *

Water:

Score: 0L

Basis:* Hydrolysis half life = 8 days (Prelim.,1987)
Associated with particulate matter in surface microlayer (OMOE,1991)
it will decompose in the presence of light to di and tri compounds, the end product being inorganic lead (OMOE,1991)

Sediment:

Score: *

Air:

Score: *

Bioaccumulation:

Score: 4

Basis:* BCF Brook trout: 42 (Prelim.,1987)
* BCF Bluegill: 45 (Prelim.,1987)
BCF 4 F.W. invert. sp. 499-1700 (Prelim.,1987)
BCF Mussels (S.W.) 2570 (Prelim.,1987)
BCF Oysters (S.W.) 1400 (Prelim.,1987)
Log Kow: 4.57 (calc.) (Prelim.,1987)

Toxicity:

Acute Aquatic:

Score: 10

Basis: Score based on acute toxicity to several aquatic organisms:

Mussels: 96h LC50: 0.1 mg/l
Brown shrimp: 96h LC50: 0.02 mg/l
Bass (young): 48h LC50: 0.065 mg/l
Bluegills: 48h LC50: 1.4,2.0 mg/l
Bluegills: 96h LC50: 0.02 mg/l
Plaice: 96h LC50: 0.23 mg/l

Thiourea 62-56-6

Persistence:

Soil:

Score: 10L

Basis: $T_{\frac{1}{2}}$ = 1 to 7 days based upon estimated aqueous aerobic biodegradation half life (SRC,1989)

* can degrade by both chemical and microbial degradation although elevated levels over extended periods of time may suppress microflora activity (Prelim.,1990)
* persisted in soil for in excess of 15 weeks (Prelim.,1990)

Water:

Score: 10Q

Basis: $T_{\frac{1}{2}}$ = 1 to 7 days based upon estimated aqueous aerobic biodegradation half life (SRC,1989)

* In natural sunlit water the estimated half life for reaction with hydroxyl radicals is 171 days (Prelim.,1990)

Hydrolysis, volatilization, adsorption to sediments, and bioconcentration are not expected to be important aquatic fate processes (Prelim.,1990)

In a 5 day test using 0.05 ppm 16.8% was given off as CO_2 (Prelim.,1990)

* Biodegradation: activated sludge: aerobic: 25°C: 100 ppm: 14d: 0-29% BODT: MITI screening test: confirmed to be biodegradation resistant (Prelim.,1990)

Sediment:

Score: *

Basis: Hydrolysis, volatilization, adsorption to sediments, and bioconcentration are not expected to be important aquatic fate processes (Prelim.,1990)

Air:

Score: 0E

Basis:* $T_{\frac{1}{2}}$ = 1.6 to 16 hours based upon estimated photooxidation half life in air (SRC,1989)

Wet and dry deposition of particles may be significant removal process (Prelim.,1990)

* Reaction with photochemically produced hydroxyl radicals at a significant rate is likely (Prelim.,1990)

Thiourea **62-56-6**

Bioaccumulation:
Score: 0L

Basis: * Log Kow: -2.38 (Prelim.,1990)
* Log Kow: -1.02 (Prelim.,1990)
* Log Kow: -0.95 (Prelim.,1990)
* Log Kow: -0.98 (Prelim.,1990)
* Log Kow: -1.11 (Prelim.,1990)

Toxicity:

Carcinogenicity:
Score: 10

Basis: Score supported by IARC designation (Group 2B) sufficient evidence of carcinogenicity to animals, possible human carcinogen, positive studies in rats (see preliminary assessments for complete data set) and evidence of direct interaction with DNA.

Uranium

Persistence:

Soil:
Score: 10

Basis: Uranium is an element

Water:
Score: 10

Basis: Uranium is an element

Sediment:
Score: 10

Basis: Uranium is an element

Air:
Score: 10

Basis: Uranium is an element

Bioaccumulation:
Score: 4Q

Basis: BCF Clam: (Valve analyzed): 2.8-3.5 (Prelim.,1988)
* BCF Clam: (Viscera analyzed): 26-42 (Prelim.,1988)

Toxicity:

Mammalian Inhalation:
Score: 10

Basis: Score based on rat data indicating a NOAEL of 0.07 mg/kg/d:
rat: oral (drinking water): hexavalent U: 11 months: NOAEL 0.6 mg/l=0.07 mg/kg/d (rat drinking 110 ml/kg/d).

Mammalian Oral:
Score: 10

Basis: Score based on assuming that NOAEL is < 0.2 mg/kg/d in dog:
dog: oral: soluble U: 1 year: 0.2 mg/kg/d: "tolerated" with adverse effects on growth by latter after 1 yr.

Zinc 7440-66-6

Persistence:

Soil:
Score: 10

Basis: Zinc is an element

Water:
Score: 10

Basis: Zinc is an element

Sediment:
Score: 10

Basis: Zinc is an element

Air:
Score: 10

Basis: Zinc is an element

Bioaccumulation:
Score: 4L

Basis:* BCF Fish: 51 (OMOE,1987)
* BCF Fish: 432 (OMOE,1987)
BCF Invertebrate: 107 (OMOE,1987)
BCF Invertebrate: 1130 (OMOE,1987)
Benthic Organisms tend to accumulate more zinc than other organisms at higher trophic levels (OMOE,1990c)

Toxicity:

Acute Aquatic:
Score: 10

Basis: Score based on reported 96h LC50 values of < 0.1 mg/l for several aquatic species:

Rainbow trout fry: 0.066mg/l
Rainbow trout: 0.093mg/l
Chinook salmon: 0.084mg/l
Ceriodaphnia dubia: 0.032mg/l
Other reported LC50 values support a somewhat lower score (i.e. 8). Acute zinc toxicity is greatly modified by pH and water hardness i.e. toxicity is enhanced in softwater and low pH.

Zinc

7440-66-6

Mammalian Inhalation:

Score: 10Q

Basis: Score based on adverse pulmonary effects observed in rats exposed by inhalation to 15 mg/m^3 (approx. 1 mg/kg/d) zinc oxide for up to 56 days.A safety factor of 100 was used since the reported value is a LOAEL and the study duration was less than 90 days resulting in a NOAEL of 0.15 mg/m^3. A Q tag was therefore assigned.

Part II: "Group A" Substances on the Secondary List

Part III: "Group B" Substances on the Secondary List

Aluminum 7429-90-5

Persistence:

Soil:
Score: 10

Basis: Aluminum is an element

Water:
Score: 10

Basis: Aluminum is an element

Sediment:
Score: 10

Basis: Aluminum is an element

Air:
Score: 10

Basis: Aluminum is an element

Bioaccumulation:
Score: 7

Basis: BCF Rainbow trout: 9.6 (OMOE,1988)
BCF Yellow Perch: 200 OMOE,1988)
* BCF Brown trout: 328-594 (OMOE,1988)
* BCF Channel catfish: 5720 (OMOE,1988)
* BCF Largemouth bass: 7010 (OMOE,1988)
* BCF Gizzard Shad: 7480 (OMOE,1988)

Aluminum **7429-90-5**

Toxicity:

Acute Summary:
Score: 8

Basis: Score based on the aquatic toxicity of aluminum to fish. Toxicity is strongly dependent on pH and levels of dissolved organic cabon which govern the nature and availability of aluminum to aquatic organisms. Provincial water quality guidelines have been developed which consider the toxicity of aluminum in terms of inorganic/inorganic monomeric forms (pH 4.5-6.5) and total aluminum (pH > 6.5-9.0). In the latter case it is not feasible to separate inorganic and organic forms. In general terms the acute/sub-acute toxicity of aluminum is most evident in the range 0.1 to 1.0 mg/l at low pH values. (Source: MOE, PWQG, 1988):

a) inorganic aluminum (pH 4.5-6.5)

Rainbow trout (fry): 120h LC50: pH 5.1-5.3: 0.175 mg/l
Atlantic salmon (presmolts): 50h LC100: pH 5.0: 0.245 mg/l
Shiners (adults): 7h LC50-100: pH 5.0: 0.07-0.160 mg/l
Atlantic salmon (smolts): 36h LC100: pH 4.6: 0.05-0.065 mg/l
Atlantic salmon (adults): 35h : pH 5.2-5.5: 0.109-0.133 mg/l: mortality

b) total aluminum (pH > 6.5-9.0)

Rainbow trout (eggs): 8d: LC56: pH 7.2: 0.500 mg/l
Rainbow trout (fingerlings): 44d LC50: pH 7.3-7.6: 0.513 mg/l
Rainbow trout (embryos and fry): 28d: EC50 (death and deformity): pH 7.4: 0.560 mg/l
Goldfish: 7d EC50 (death and deformity): pH 7.4: 0.150 mg/l
Largemouth bass: 8d: LC50: pH 7.2-7.8: 0.170 mg/l

Chlorobenzene

108-90-7

Persistence:

Soil:

Score: 10W

Basis: Volatile if released on moist soil, relatively mobile in sandy soil and biodegrades in these soils, therefore it can be expected to leach into groundwater (Howard,1989)
fairly rapid mineralization, 20% per week (Howard,1989)
Column test using sandy soil: 27% volatilized, 23-33% percolated through, 40-50% was not accounted for (Howard,1989)
* $T_{\frac{1}{2}}$ = 68 to 150 days based upon estimated aqueous aerobic biodegradation (SRC,1989)
* Biodegradation slow, acclimation is an important factor (Prelim.,1987)

Water:

Score: 0

Basis:* Primary loss from water will be evaporation (Howard,1989)
* estimated half life for evaporation range between 1 and 12 hours for a rapid stream (Howard,1989)
Biodegradation will occur in warmer seasons, more rapid in freshwater then estuarine, $T_{\frac{1}{2}}$ estuarine = 75 days (Howard,1989)
$T_{\frac{1}{2}}$ = 68 to 150 days based upon unacclimated aerobic river die-away tests (SRC,1989)
* $T_{\frac{1}{2}}$ evaporation = 4.5 hours (Prelim.,1987)
Biodegradation slow, acclimation is an important factor (Prelim.,1987)

Sediment:

Score: *

Basis: Moderate adsorption to sediments (Howard,1989)

Air:

Score: 0

Basis:* Reaction with hydroxyl radicals is the dominant removal mechanism with an estimated half life of 17 days with the formation of chlorophenols (Howard,1989)
* $T_{\frac{1}{2}}$ = 3.0 to 30.4 days for photooxidataion (SRC,1989)
* $T_{\frac{1}{2}}$ = 9.0 days for reaction with hydroxyl radicals (Prelim.,1987)

Chlorobenzene **108-90-7**

Bioaccumulation:
Score: 7

Basis: Log BCF Fathead minnow: 2.65 (446.7) (Ma et al.,1990)
Log BCF Golden Ide: 1.88 (75.9) (Ma et al.,1990)
* BCF Mosquitofish: 645 (Prelim.,1987)
BCF Snail: 1313 (Prelim.,1987)
Log Kow: 2.84 (Howard,1989)
Log Kow: 2.65 (Ma et al.,1990)
Log Kow: 2.8 (Ma et al.,1990)
Log Kow: 2.98 (Ma et al.,1990)
Log Kow: 2.99 (Ma et al.,1990)
Log Kow: 2.898 (Ma et al.,1990)
Log Kow: 2.83 (Ma et al.,1990)
Log Kow: 3.79 (Ma et al.,1990)

Toxicity:

Acute Aquatic:
Score: 8W

Basis: Score based on worst case data:
Rainbow trout (embryo/larval):96 h LC50: 0.11 mg/l
Rainbow trout: 48 h LC50: 4.1 mg/l
Rainbow trout (eggs): complete lethality 16 d:0.2-27.3 mg/l

Hexachlorobutadiene

87-68-3

Persistence:

Soil:

Score: 10E

Basis: Evaporation expected to be significant (Howard,1989)
Biodegradation may occur in aerobic zones (Howard,1989)
expected to adsorb to organic matter and not expected to rapidly migrate (Howard,1989)
* $T_{\frac{1}{2}}$ = 4 weeks to 6 months based on estimated aqueous aerobic biodegradation (SRC,1989)

Water:

Score: 10E

Basis: may biodegrade in natural environment since 100% biodegraded in aerobic batch culture in 7 days (Howard,1989)
* estimated half life for rivers is 3-30 days, for lakes and groundwater $T_{\frac{1}{2}}$ (est.) = 30-300 days based upon monitoring data (Howard,1989)
* $T_{\frac{1}{2}}$ = 4 weeks to 6 months based on estimated aqueous aerobic biodegradation (SRC,1989)

Sediment:

Score: *

Air:

Score: 10E

Basis: should degrade primarily by addition of photochemically derived hydroxyl radicals to its double bonds (Howard,1989)
* By analogy to tetrachloroethylene $T_{\frac{1}{2}}$ est. = 2 months, using mass balance approach $T_{\frac{1}{2}}$ est. = 1.6 years (Howard,1989)
* $T_{\frac{1}{2}}$ = 119.4 days to 3.3 years estimated based upon photooxidation (SRC,1989)

Bioaccumulation:

Score: 10

Basis:* BCF Rainbow trout: 17000 (Howard,1989)
BCF Rainbow trout: 5800 (Howard,1989)
Log Kow: 4.90 (Howard,1989)

Hexachlorobutadiene **87-68-3**

Toxicity:

Acute Aquatic:
Score: CMR 7

Basis: Score based on fish 96 h LC50s of < 1 mg/l:
Rainbow trout: 0.320 mg/l
Fathead minnow: 0.102 mg/l
Bluegill: 0.326 mg/l

Chronic Aquatic:
Score: CMR 7

Basis: Score based on MATC for Fathead minnows 0.0092 mg/l.

Hexachloroethane 67-72-1

Persistence:

Soil:

Score: 10L

Basis: Chemical hydrolysis is not expected to be an important fate process (Prelim.,1990)
It may volatilize slowly from dry soil surfaces (Prelim.,1990)
* It may persist for a long time in unadapted soil, the half life is estimated at greater than 2 years (Prelim.,1990)
* In a sandy aquifer hexachloroethane had become undetectable after 330 days (Prelim.,1990)

Water:

Score: 0

Basis: Less than 30% biodegradation in 2 weeks using activated sludge under aerobic conditions (Prelim.,1990)
In a static 7 day test using wastewater inoculum 100% was degraded (Prelim.,1990)
* Biodegradation is not expected to be an important fate process in natural water (Prelim.,1990)
* The evaporation half life was measured for a 1ppm solution with still air and an average depth of 6.5 cm, $T_{\frac{1}{2}}$ = 40.7 minutes at 25°C (Prelim.,1990)
* The estimated half life for volatilization from a model river is 15 hours (Prelim.,1990)
$T_{\frac{1}{2}}$ = 4 weeks to 6 months based upon estimated aqueous aerobic biodegadation half life (SRC,1989)

Sediment:

Score: *

Basis: based on the Koc value of 960 for hexachloroethane it is expected to adsorb moderately to slightly to suspended solids and sediment (Howard,1989)

Hexachlorobutadiene **87-68-3**

Toxicity:

Acute Aquatic:
Score: CMR 7

Basis: Score based on fish 96 h LC50s of < 1 mg/l:
Rainbow trout: 0.320 mg/l
Fathead minnow: 0.102 mg/l
Bluegill: 0.326 mg/l

Chronic Aquatic:
Score: CMR 7

Basis: Score based on MATC for Fathead minnows 0.0092 mg/l.

Hexachloroethane 67-72-1

Persistence:

Soil:

Score: 10L

Basis: Chemical hydrolysis is not expected to be an important fate process (Prelim.,1990)
It may volatilize slowly from dry soil surfaces (Prelim.,1990)
* It may persist for a long time in unadapted soil, the half life is estimated at greater than 2 years (Prelim.,1990)
* In a sandy aquifer hexachloroethane had become undetectable after 330 days (Prelim.,1990)

Water:

Score: 0

Basis: Less than 30% biodegradation in 2 weeks using activated sludge under aerobic conditions (Prelim.,1990)
In a static 7 day test using wastewater inoculum 100% was degraded (Prelim.,1990)
* Biodegradation is not expected to be an important fate process in natural water (Prelim.,1990)
* The evaporation half life was measured for a 1ppm solution with still air and an average depth of 6.5 cm, $T_{\frac{1}{2}}$ = 40.7 minutes at 25°C (Prelim.,1990)
* The estimated half life for volatilization from a model river is 15 hours (Prelim.,1990)
$T_{\frac{1}{2}}$ = 4 weeks to 6 months based upon estimated aqueous aerobic biodegadation half life (SRC,1989)

Sediment:

Score: *

Basis: based on the Koc value of 960 for hexachloroethane it is expected to adsorb moderately to slightly to suspended solids and sediment (Howard,1989)

Hexachloroethane **67-72-1**

Air:

Score: 10

Basis:* Persistent in troposphere, longe range transport is expected (Prelim.,1990)
* The half life for diffusion to the stratosphere is approximately 30 years (Prelim.,1990)
* In the stratosphere photodegradation may be an important fate process (Prelim.,1990)
* the half life of hexachloroethane in air is years (Prelim.,1990)
* $T_{\frac{1}{2}}$ = 7.3 to 73 years based upon estimated maximum for rate constant reaction with hydroxyl radicals (SRC,1989)

Bioaccumulation:

Score: 7

Basis: BCF Bluegill sunfish: 139 (Prelim.,1990)
* BCF Rainbow trout: 513-1202 (Prelim.,1990)
* BCF Rainbow trout: 510 (Prelim.,1990)
Log Kow: 4.04 (Prelim.,1990)
Log Kow: (calc.) 3.34 (Prelim.,1990)
Log Kow: 3.82 (Howard,1989)

Toxicity:

Acute Aquatic:

Score: 8

Basis: Score based on 96h Rainbow trout and Bluegill LC50 values:

Fathead minnow: 96h LC50: 1.53 mg/l
Fathead minnow: 96h LC50: 1.32 mg/l
Rainbow trout: 96h LC50: 0.98 mg/l
Daphnia sp.: 96h LC50: 8.07 mg/l
Bluegill: 96h LC50: 0.98 mg/l
Midges: 96h LC50: 1.7 mg/l

Mammalian Oral:

Score: 8

Basis: Score based on a 16 wk rat oral NOEL study:

rat: oral (diet): 16 wks: 1, 15, or 62 mg/kg/d: 15 mg/kg/d: atrophy and degeneration of renal tubules observed in males; no effects seen in females: NOEL: 1 mg/kg/d

Pentachlorobenzene **608-93-5**

Persistence:

Soil:

Score: 10

Basis:* $T_{\frac{1}{2}}$ = 194 to 345 days based upon unacclimated aerobic soil grab sample data (SRC,1989)
* $T_{\frac{1}{2}}$ = 0.5 to 1 year, not expected to leach into groundwater (Prelim.,1987)

Water:

Score: 10E

Basis:* $T_{\frac{1}{2}}$ = 194 to 345 days based upon estimated unacclimated aqueous aerobic biodegradation (SRC,1989)
$T_{\frac{1}{2}}$ = 4.7 hours for evaporation, however this is not expected to be a significant process (Prelim.,1987)

Sediment:

Score: *

Basis:

Air:

Score: 10E

Basis:* $T_{\frac{1}{2}}$ = 45.3 days to 1.2 years based upon estimated rate constant for the vapour phase reaction with hydroxyl radicals in air (SRC,1989)
* $T_{\frac{1}{2}}$ estimated = 5.68 years, expected o be carried long distances (Prelim.,1987)

Bioaccumulation:

Score: 7

Basis: BCF Rainbow trout: 13000-20000 (Prelim.,1987)
* BCF Guppy: lipid content:5000-6900 (Prelim.,1987)
BCF Guppy: lipid content: 260,000 (Prelim.,1987)
* BCF Bluegill: 3400 (Prelim.,1987)
Log Kow: 5.17 (Prelim.,1987)
Log Kow: 5.69 (calc) (Prelim.,1987)
Log Kow: 4.88 (meas) (Prelim.,1987)

Pentachlorobenzene **608-93-5**

Toxicity:

Acute Aquatic:
Score: 8

Basis: Score based on acute toxicity of pentachlorobenzene to fish:

Bluegill: 96h LC50: 0.25 mg/l
Bluegill: 48h LC50: 0.55 mg/l
Bluegill: 24h LC50: 2.27 mg/l
Sheepshead minnow: 96h LC50: 0.83 mg/l
Sheepshead minnow: 48h LC50: 9.55 mg/l
Sheepshead minnow: 24h LC50: > 32.0 mg/l
Guppy: LC50: 0.177 mg/l
Guppy: 14d LC50: 0.178 mg/l

2,4,5-Trichlorophenol **95-95-4**

Persistence:

Soil:

Score: 10Q

Basis: adsorption is moderate to extensive (Prelim.,1990)
In a soil suspension 100% biodegradation occured in >47 days (Prelim.,1990)
* In a 160 day test under aerobic conditions using a clay loam 9% degradation occured in sterile soil and 72% was degraded in non-sterile soil (Prelim.,1990)
* In an 80 day test under anaerobic conditions using a clay loam 5% degradation occured in sterile soil and 8% was degraded in non-sterile soil (Prelim.,1990)
* $T_{\frac{1}{2}}$ = 23 to 690 days based upon estimated unacclimated aqueous aerobic biodegradation (SRC,1989)
* If released to soil 2,4,5-trichlorophenol would be subject to biodegradation at a rate which would depend upon conditions such as temperature, the availability of oxygen, and the presence of the appropriate organisms (Howard,1991)
* In an 80 day test under anaerobic conditions there was only an 8% loss, only 38% of this loss was attributable to biodegradation (Howard,1991)
* The presence of 2,4,5-Trichlorophenol in relatively deep soils at certain sawmills and in the leachate from landfills suggests that leaching is possible under the appropriate conditions (Howard,1991)
* It will not hydrolyze in soil (Howard,1991)
Photomineralization on soil surfaces may be an important loss mechanism (Howard,1991)
* Based upon the Henry's Law constant, volatilization from moist near surface soil may be a significant, although probably slow removal process (Howard,1991)

2,4,5-Trichlorophenol **95-95-4**

Water:

Score: 0

Basis: 100% was biodegraded in suspended soils in > 72 days (Prelim.,1990)
$T_{\frac{1}{2}}$ = 690 days in water column (Prelim.,1990)
$T_{\frac{1}{2}}$ for volatilization from a model river is 13 days, this is not expected to be an important fate process (Prelim.,1990)
MITI biodegradation using activated sludge and a solution of 100µg/L had a half life of 15 days (Prelim.,1990)
It will strongly adsorb to suspended solids and sediment (Prelim.,1990)
* The half life for photolysis under midday sunlight is 0.6 hours for summer, and 1 hour for winter (Prelim.,1990)
* $T_{\frac{1}{2}}$ = 0.5 hours to 14 days based upon aqueous photolytic half life (SRC,1989)
* Beyond the reach of light this compound is expected to bioaccumulate significantly in aquatic organisms (Howard,1991)
* Volatilization from the water surface is not expected to be a significant fate process (Howard,1991)
This chemical is not susceptible to hydrolysis (Howard,1991)
2,4,5-Trichlorophenol will be partially ionized at many environmental pHs base on its measured pKa of 7.43 at 25°C; this would indicate that its fate and transport in aquatic media would be affected by pH (Howard,1991)

Sediment:

Score: 4

Basis:* $T_{\frac{1}{2}}$ = 23 for biodegradation in sediment (Prelim.,1990)
* It will strongly adsorb to suspended solids and sediment (Prelim.,1990)
* In sediments biodegradation is expected to be an important removal process (Howard,1991)

2,4,5-Trichlorophenol **95-95-4**

Air:

Score: 0

Basis:* $T_{\frac{1}{2}}$ for photolysis is 4 days (Prelim.,1990)
* Photodecomposition is expected to be the predominant fate process for this compound (Prelim.,1990)
* $T_{\frac{1}{2}}$ = 1.3 to 12.6 days based upon photooxidation half life in air (SRC,1989)
* Vapour phase photolysis/photooxidation experiments have predicted that, both processes will be important in the atmosphere with an estimated half life of 7.5 days (Howard,1991)

Detection of this compound in rain and snow samples indicate that removal by percipitation can occur (Howard,1991)

Bioaccumulation:

Score: 7

Basis: BCF Goldfish: 62 (Prelim.,1990)
* BCF Fathead minnow: 4.8 µg/L: 1800 (Prelim.,1990)
* BCF Fathead minnow: 49.3 µg/L: 1900 (Prelim.,1990)

Beyond the reach of light this chemical is expected to bioaccumulate significantly, adsorbing to suspended solids and sediments (Prelim.,1990)
Log Kow: 3.72 (Prelim.,1990)
Log Kow: 3.96 (Prelim.,1990)
Log Kow: 4.10 (Prelim.,1990)
Log Kow: 3.06 (Prelim.,1990)

Toxicity:

Acute Aquatic:

Score: 8

Basis: Score based on 96h LC50s to fish:

Bluegill: 96h LC50: 0.45 mg/l
Rainbow trout: 48h LC50: 1.0 mg/l
Goldfish: 24h LC50: 1.7 mg/l
Bluegill: 24h LC50: 0.61 mg/l
Bluegill: 96h LC50: 0.45 mg/l
Brown trout: 24h LC50: 0.9 mg/l

Triphenyl Phosphate **115-86-6**

Persistence:

Soil:

Score: 7L

Basis:* biodegradation half life of 50 to 60 days for sediment and hydrosoil (Prelim.,1990)

Water:

Score: 0

Basis:* River die-away test, 100% degraded in 4 days (CMR,1981)
Hydrolysis half life at pH 7 = 19 days (CMR,1981)
* Hydrolysis half life at pH 9 = 3 days (CMR,1981)
* Hydrolysis half life at pH 8.2 = 7.5 days if pH is natural or acid hydrolysis is too slow to measure (Prelim.,1990)
Photolysis $T_{\frac{1}{2}}$ in natural waters = 13.5 days, in distilled water $T_{\frac{1}{2}}$ = 16 days (Prelim.,1990)
* Mississippi river die away test: 25°C: 0.05 ppm: aerobic: 50% primary degradation: 2-4 day incubation (Prelim.,1990)

Sediment:

Score: 7L

Basis:* biodegradation half life of 50 to 60 days for sediment and hydrosoil (Prelim.,1990)

Air:

Score: *

Basis:

Bioaccumulation:

Score: 10

Basis: BCF Rainbow trout: 420 (CMR,1981)
BCF Fathead minnow: 561 (CMR,1981)
Log Kow: 4.63 (CMR,1981)
BCF Goldfish: 3-4d: 151 (Prelim.,1990)
* BCF Rainbow trout: (range): 130-19055 (Prelim.,1990)

Triphenyl Phosphate **115-86-6**

Toxicity:

Acute Aquatic:
Score: CMR 7

Basis: Score based on 96h LC50s in Rainbow trout and Fathead minnows of 0.36 and 0.66 mg/l respectively.

Part IV: "Group C" Substances on the Secondary List

4-Chlorophenylphenyl ether (1-chloro-4-phenoxybenzene) 7005-72-3

Persistence:

Soil:
Score: *

Water:
Score: 0E

Basis:* The estimated half life for evaporation from a pond 1 metre deep is approximately 7 hours (U.S. EPA, 1979)

Sediment:
Score: *

Air:
Score: *

Bioaccumulation:
Score: 7

Basis:* BCF Rainbow trout (muscle): 736 (CMR,1984)
* BCF Rainbow trout: 550 (Ma et al.,1990)
Log Kow: 4.08 (U.S. EPA,1979)
Log Kow: 5.08 (Ma et al.,1990)
Log Kow: 5.55 (Ma et al.,1990)

Toxicity:

Acute Aquatic:
Score: CMR 7

Basis: Score based on aquatic organism data:

Daphnia sp.: 96h LC50: 0.39 mg/l
Fathead minnow: 96h LC50: 1.75 mg/l

Palustric Acid **1945-53-5**

Persistence:

Soil:
Score: *

Basis:

Water:
Score: *

Basis:

Sediment:
Score: *

Basis:

Air:
Score: *

Basis:

Bioaccumulation:
Score: 10L

Basis:* Log Kow: 6.25 (Prelim.,1989)

Toxicity:

Acute Aquatic:
Score: 8L

Basis: Score based on acute toxicity of palustric acid to Rainbow trout:

Rainbow trout (juveniles): 96h LC50: 0.32 mg/l (palustric resin acid)
Rainbow trout: 96h LC50: 0.55 mg/l

Selenium 7782-49-2

Persistence:

Soil:
Score: 10

Basis: Selenium is an element

Water:
Score: 10

Basis: Selenium is an element

Sediment:
Score: 10

Basis: Selenium is an element

Air:
Score: 10

Basis: Selenium is an element

Bioaccumulation:
Score: *

Basis: rapidly and efficiently taken up through the digestive tract of fish (OMOE,1987)

Toxicity:

Acute Aquatic:
Score: 8

Basis: Score based on toxicity to fish. Most aquatic invertebrate 96h EC50s are in the range of 0.246 (*Daphnia* sp.) to 42.5 mg/l (Midges). The 96h LC50s for fish range from 0.62 mg/l for Fathead minnows to 66 mg/l for Channel catfish juveniles, although most species are in the range of 1-10 mg/l.

Selenium **7782-49-2**

Teratogenicity:

Score: 6

Basis: Score based on presentation of developmental anomalies without overt maternal toxicity in the range 0.1 to 1.0 mg/kg/d; no frank teratogenic effects:

mouse: oral (drinking water): 0.23-10 mg/kg/d sodium selenite: 11 day pregestation: 10 mg/kg/d: 5/30 delivered, reduced fetal weights.
mouse: oral (drinking water): 0.45 mg/kg/d sodium selenate: 3 generations: increased number of runts, fewer litters in third generation.
mouse: oral (drinking water): 0.15-0.75 mg/kg/d: potassium selenate: 0.75 mg/kg/d: reduced fertility, decreased number of survivals, reduced body weight of young, reduced body weight in adults.
mouse: oral (drinking water): 0.45, 0.90 mg/kg/d sodium selenite: 30 days: 0.90 mg/kg/d: reduced fetal body weights, increased number of ossified vertebrae, no teratogenic effects.
duck: oral: 0.1-10 mg/kg/d sodium selenite: 4 wks before egg laying: 1.0, 2.5 mg/kg/d: reduced survival of hatchlings, embryotoxicity: 100 mg/kg/d: high mortality
mouse: NOAEL: 0.45 mg/kg/d
rat: NOAEL: 0.25 mg/kg/d

1,2,3,5-Tetrachlorobenzene 634-90-2

Persistence:

Soil:
Score: *

Basis:

Water:
Score: *

Basis:

Sediment:
Score: *

Basis:

Air:
Score: *

Basis:

Bioaccumulation:
Score: 7

Basis:* BCF Bluegill: 28d: 1800 (CESARS,1990)
* BCF Fathead minnow: 1820 (Ma et al.,1990)
BCF Guppy: 72443 (Ma et al.,1990)
* BCF fish: 3890 (Ma et al.,1990)
Log Kow: measured: 4.46 (CESARS,1990)
Log Kow: estimated: 3.88 (CESARS,1990)
Log Kow: 5.05 (Ma et al.,1990)
Log Kow: 4.5 (Ma et al.,1990)
Log Kow: 4.53 (Ma et al.,1990)
Log Kow: 4.51 (Ma et al.,1990)
Log Kow: 4.52 (Ma et al.,1990)
Log Kow: 4.65 (Ma et al.,1990)
Log Kow: 4.658 (Ma et al.,1990)

1,2,3,5-Tetrachlorobenzene **634-90-2**

Toxicity:

Acute Aquatic:
Score: 8W

Basis: Score based on acute toxicity to freshwater invertebrates (Daphnia sp.). Most vertebrates rate a lower score:

Daphnia sp.: 48h LC50: 0.86 mg/l
Bluegill: 24h LC50: 59 mg/l
Bluegill: 96h LC50: 6.4 mg/l
Sheepshead minnow: 24h LC50: 7.5 mg/l
Sheepshead minnow: 48h LC50: 5.6 mg/l
Sheepshead minnow: 72h LC50: 4.7 mg/l
Sheepshead minnow: 96h LC50: 3.7 mg/l

Tetrachloroguaiacol **2539-17-5**

Persistence:

Soil:
Score: *

Basis:

Water:
Score: *

Basis: Biodegradation by bacteria can occur (Ma et al.,1990)

Sediment:
Score: *

Basis:

Air:
Score: *

Basis:

Bioaccumulation:
Score: 7

Basis: BCF Rainbow trout: blood: caged: 40-80 (CESARS,1989)
* BCF Atlantic Salmon: pH 4.5: 1200 (CESARS,1989)
* BCF Atlantic Salmon: pH 6.3: 1400 (CESARS,1989)
BCF Bleak: brackish test: 400 (CESARS,1989)
Log Kow: 4.45 (Prelim.,1987)
Log Kow: 4.76 (Ma et al.,1990)
Log Kow: 4.53 (Ma et al.,1990)
Log Kow: 5.01 (Ma et al.,1990)

Toxicity:

Acute Aquatic:
Score: 8

Basis: Score based on acute toxicity to fish:

Rainbow trout: 96h LC50: 0.2-0.4 mg/l
Rainbow trout: 96h LC50: 0.35 mg/l
Rainbow trout: 96h LC50: 0.32 mg/l
Bleak: 96h LC50: 0.110 mg/l: pH 7.0
Bleak: 96h LC50: 0.067 mg/l: pH 6.0
Bleak: 96h LC50: 0.056 mg/l: pH 5.0

2,3,4,5-Tetrachlorophenol **4901-51-3**

Persistence:

Soil:
Score: *

Basis: The log Koc value of 3.84 (calc) indicates a high potential for soil partitioning (CESARS,1989)

Water:
Score: *

Basis:

Sediment:
Score: *

Basis:

Air:
Score: *

Basis:

Bioaccumulation:
Score: 7L

Basis:
* Log Kow: calc: 4.60 (CESARS,1989)
* Log Kow: meas: 4.82 (CESARS,1989)
* Log Kow: meas: 4.68 (CESARS,1989)
* Log Kow: calc: 4.48 (CESARS,1989)
* Log Kow: calc: 5.16 (CESARS,1989)
* Log Kow: meas: 4.21 (CESARS,1989)
* Log Kow: 5.03 (Ma et al.,1990)
* Log Kow: 4.95 (Ma et al.,1990)

Toxicity:

Acute Aquatic:
Score: 8

Basis: Score based on acute toxicity to Guppy, Fathead minnow, and Rainbow trout:

Guppy: unreported duration: LC50: 0.77 mg/l
Guppy: unreported duration: LC50: 2.32 mg/l
Guppy: unreported duration: LC50: 0.44 mg/l
Fathead minnow: 24h LC50: 0.496 mg/l
Fathead minnow: 48h LC50: 0.450 mg/l
Fathead minnow: 72h LC50: 0.441 mg/l
Fathead minnow: 96h LC50: 0.441 mg/l
Rainbow trout: 24h LC50: 0.304 mg/l
Rainbow trout: 48h LC50: 0.284 mg/l
Rainbow trout: 72h LC50: 0.284 mg/l
Rainbow trout: 96h LC50: 0.205 mg/l

1,2,3-Trichlorobenzene 87-61-1

Persistence:

Soil:
Score: *

Basis:

Water:
Score: *

Basis:

Sediment:
Score: *

Basis:

Air:
Score: *

Basis:

Bioaccumulation:
Score: 7

Basis: BCF Guppy: 13000 (CMR,1984)
BCF Rainbow trout: Eyed egg: 108 (CMR,1984)
* BCF Rainbow trout: hatching: 710 (CMR,1984)
BCF Rainbow trout: alevin: 52 (CMR,1984)
* BCF Rainbow trout: 2600 (CMR,1984)
* BCF Rainbow trout: 1200 (CMR,1984)

1,2,3-Trichlorobenzene **87-61-1**

Toxicity:

Acute Aquatic:
Score: CMR 7

Basis: Score based on sensitivity of a number of aquatic species:

Guppy: 36h LC50: 2.34 mg/l
Rainbow trout: 48h LC50: 0.71 mg/l
Daphnia sp.: 24h LC50: 0.35 mg/l
Daphnia sp.: 48h LC50: 2.72 mg/l

Chronic Aquatic:
Score: CMR 7

Basis: Score based on fertility tests with *Daphnia magna* reporting the 14d EC50 and EC16 to be 0.20 mg/l and 0.06 mg/l respectively.

Trixylyl Phosphate 25155-23-1

Persistence:

Soil:
Score: *

Basis:

Water:
Score: *

Basis: Susceptible to hydrolysis (Ma et al.,1990)
Biodegradable in SCAS test (Ma et al.,1990)

Sediment:
Score: *

Basis:

Air:
Score: *

Basis:

Bioaccumulation:
Score: 7L

Basis:* Log Kow: 5.6 (Ma et al.,1990)
* Log Kow: 5.63 (Ma et al.,1990)
* Log Kow: 5.26 (Ma et al.,1990)
* Log Kow: 5.7 (Ma et al.,1990)
Log Kow: 6.4-6.6 (Ma et al.,1990)

Toxicity:

Acute Aquatic:
Score: 8W

Basis: Score based on an aquatic 96h LC50 range for 3 triaryl phosphates. A W is assigned because the LC50 of trxylyl phosphate itself (within the range) was not specified, thus the upper limit of the range was used.

Harpacticoid (Nitocra spinipes): 96h LC50: 0.27-1.75 mg/l
Zebra fish: 96h LC50: 0.27-1.75 mg/l

Appendix 'B'

Lists of Candidate Substances for Bans or Phase-Outs Including Hazard Assessment Scores

Ontario Ministry of the Environment
Hazardous Contaminants Branch
10/04/92

PRIMARY LIST: Candidate Substances for Bans or Phase-Outs · Persistent AND Bioaccumulative AND Toxic

Substance Name	CAS Number	PERSISTENCE SUM	PERSISTENCE AIR	PERSISTENCE AQ.	PERSISTENCE SOIL	PERSISTENCE SED.	BIOCONC. SUM	ACUTE SUM	ACUTE INHL	ACUTE DERM	ACUTE AQUA	ACUTE ORAL	SUBLETHAL HUMAN SUM	SUBLETHAL HUMAN AQUA	SUBLETHAL HUMAN TER	PHYTOTOX SUM	PHYTOTOX AQUA	PHYTOTOX TER	SUBLETHAL HUMAN SUM	SUBLETHAL HUMAN INHL	SUBLETHAL HUMAN ORAL	TERATOGEN	CARCINOGEN	IARC GROUP
anthracene	120-12-7	10	0E	0E	7	10Q	7	10Q			10Q												2L	3
arsenic	7440-38-2	10	10	10	10	10	7Q																	1-T
benz(a)anthracene	56-55-3	10L	0E	0	10L	10E	7	10Q			10Q													M-A
benzo(a)pyrene	50-32-8	10L	0E	0E	10L	10E	7	10Q			10Q												10	
benzo(ghi)perylene	191-24-2	10	0E	*	10	10E	7L	10Q			10Q	*												
p,p'-ddd	72-54-8	10	*	10	*		7	10	*	2	10	4	10	10	*	4	4	*	2	*	2	4L	10Q	3
p,p'-dde	72-55-9	10Q	*	4	10Q		7	10	*	*	10	2	10	10U	*	8	8	*	4	*	4	0L	10	2
p,p'-ddt	50-29-3	10	10Q	10E	10		10	10	*	4	10	4	10Q	10Q	*	8	8	0	10	*	10	8	8	
1,4-dichlorobenzene (parsdichlorobenzene)	106-46-7	10	4	0	10L	10	7	6	*	0	6	4	2	2	*	6Q	6Q	*	4	4	4	0	10	2B
3,3'-dichlorobenzidine	91-94-1	10	0	0	10		7	2	*	0L	*	2	*	*	*	*	*	*	*	*	*	*	10	2B
dieldrin	60-57-1	10	*	10	10		10	10	8	6	10	8	10Q	10Q	6Q	8Q	8Q	0	10	10Q	10	10	10	2B
hexachlorobenzene	118-74-1	10	10	0	10	10L	10	4Q	2	*	4Q	2	8	6	8	8	8	*	10	*	10	6	10	3
alpha-1,2,3,4,5,6-hexachlorocyclohexane	319-84-6	10U	0E	10E	10U		7	8					6			2			*				10	2B
gamma-1,2,3,4,5,6-hexachlorocyclohexane (Lindane)	58-89-9	10	0E	10E	10	10	7	10	4Q	6	10	6	8	8		*	*	*	10	10	6	4	10	2B
mercury	7439-97-6	10	10	10	10	10	10Q																	
mirex	2385-85-5	10Q	*	4L	10Q		10	8	*	2L	8	4	6	6	4	10	10	6	8	8	*	8	8	M-A
pentachlorophenol	87-86-5	4	4E	0	4	10L	7	10	4	4	10	6	10E	10E	*	8	8	*	6	*	6	4	2U	7
perylene	198-55-0	10E				10E	7	10Q			10Q		*			*			*			*	*	*
phenanthrene	85-01-8	7U	0	7U	10U	*	7	10L			10L		*			*			*			*	2	
polychlorinated biphenyls	n/a	10	*	10E	*	10E	10	10					10			8Q			10Q			8	8	3
polychlorinated dibenzo-p-dioxins and -furans	n/a	10	0E	10	10	10L	10U	10	*	*	*	10U	10	*	*	0L	*	*	10	*	10L	10	8	2A
toxaphene	8001-35-2	10	10	10	10		10	10	0L	4	10	6	10	10	6	8	8	0	10	10Q	10	10Q	10	2B
tributyl tin	688-73-3	10		7	10	10	7	10	*	*	10	6	10	10	*	10	10	*	*	*	*	*	*	

Score Legs: 0 · data did not precisely match criteria, or method was unusual
U · worst-case basis
E · estimated by model or analogy
L · limited data set

SECONDARY LIST, GROUP 'A': Persistent OR Bioaccumulative AND Toxic

Substance Name	CAS Number	PERS SUM	PERS AIR	PERS AQ	PERS SOIL	PERS SED	BIOC OHC	ACUT SUM	ACUT INH	ACUT DERM	ACUT AQUA	ACUT ORAL	HUMN SUBH	HUMN AQUH	HUMN TERR	PHYT SUBH	PHYT AQUP	PHYT TERP	SUBLETHAL MAMM	SUBLETHAL MINV	SUBLETHAL MORL	TERATOGN	CARCIN
benzo(b)fluoranthene	205-99-2	10L	0E	4E	10L	10E	*	*					*			*			*			*	10
benzo(e)pyrene	192-97-2	10E				10E	*	100			100		*			*			*			*	8L
benzo[j]fluoranthene	205-82-3	10E				10E	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	10
benzo[k]fluoranthene	207-08-9	10L	0E	4L	10L	10E	*	100			100												
beryllium	7440-41-7	10	10	10	10	10	4Q																
bis(2-ethylhexyl)phthalate	117-81-7	4	0E	4	4E		7	6	4L	0	6	0	8Q	8	*	0Q	0Q	*	4	*	4	2	8	M-A
cadmium	7440-43-9	10	10	10	10	10	0	10			10					10L	10L						10	*
chloroform	67-66-3	10	7	0	10E		0	6	0	*	4	6	0	0	*	0	0	*	8U	6	8U	4	10	*
chromium (Cr+6)	7440-47-3	10	10	10	10	10	0Q																	
chrysene	218-01-9	10L	0E	7L	10L	10E	*	100			100													M-A
copper	7440-50-8	10	10	10	10	10	4Q	10	*	*	10	4	10	10	*	10	10	*	8	8	8Q	2	2Q	M-A
dibenz[a,h]acridine	226-36-8	10E			*	10E	*	*					*			*			*			*	10L	
dibenz[a,j]acridine	224-42-0	10E			*	10E	*	*					*			*			*			*	10L	
dibenzo[e,i]pyrene	189-55-9	10L	0E	10E	10L	10E	*	*					*			*			*			*	10	*
7H-dibenzo[c,g]carbazole	194-59-2	10E				10E	*	*					*			*			*			*	10	*
7,12-dimethylbenz[a]anthracene	57-97-6	10E	0E	4E	4	10E	*	10E	*	*	10E	4	6Q	6Q	*	8Q	8Q	*	6Q	*	6Q	6	10	
1,8-dinitropyrene	42397-65-9	10E	*	*	*	10E	*	*					*			*			*			*	10	
1,4-dioxane	123-91-1	10	0E	10	10E		0L	2	0	0L	0	2	*	*	*	0	0	*	4L	2	4L	0L	10	
1,2-diphenylhydrazine	122-66-7	10E	0	0	10E		4L																10	
ethylene dibromide	106-93-4	4E	4E	0	7Q		0L	4	*	4	4	4	8L	*	8Q	*	*	*	6Q	6Q	6Q	2Q	10	
hexachlorocyclopentadiene	77-47-4	0	0E	0	0		7	10	6	4	10	4	6	6	*	0L	*	0L	10	10	8	2	*	
indeno[1,2,3-cd]pyrene	193-39-5	10L	0E	10E	10L	10E	*	*					*			*			*			*	10	
lead	7439-92-1	10	10	10	10	10	4																	
pyrene	129-00-0	10L	0E	0	10L	10E	*	100			100													M-A
silver (ionic form)	7440-22-4	10	10	10	10	10	4L	10			10													M-A
styrene	100-42-5	0	0	0	7		0	4	2	*	4	4	0	0	*	0	0	*	2	2	2	0	10	
2,3,4,6-tetrachlorophenol	58-90-2	10E	10E	4E	10E		4	8					*			*			*			2L	10L	
tetraethyllead	78-00-2	10					4	10			10								10Q					
thiourea	62-56-6	10Q	0E	10Q	10L		0L	6	*	*	6	4	*	*	*	4Q	4Q	0Q	8Q	*	8Q	2Q	10	
uranium	7440-61-1	10	10	10	10	10	4Q	6			6	6	*	*	*	4	4L	4	10	10	10	*	*	
zinc	7440-66-6	10	10	10	10	10	4L	10	*	*	10	4	4	4	*	8	6	8	10Q	10Q	6Q	0	8	M-A

Substance Name	CAS Number	MICHIGAN DNR SCORES: CARCINOGEN	GENOTOX	REPRO	PERSISTENCE	BIOACCUMULATION	ACUTE AQUATIC	ACUTE MAMMALIAN	ACUTE AVIAN	CHRONIC AQUATIC	CHRONIC MAMMALIAN	CHRONIC AVIAN
benzo(b)fluoranthene	205-99-2	*	*	*	*	*	*	*	*	3	*	*
benzo(e)pyrene	192-97-2											
benzo[j]fluoranthene	205-82-3											
benzo[k]fluoranthene	207-08-9											
beryllium	7440-41-7											
bis(2-ethylhexyl)phthalate	117-81-7	M-A	*	*	3	*	*	2	*	7	2	*	*
cadmium	7440-43-9											
chloroform	67-66-3	*	*	*	7	*	*	*	*	*	*	*	*
chromium (Cr+6)	7440-47-3											
chrysene	218-01-9	M-A	*	*	1	2	2	2	*	3	2	*	*
copper	7440-50-8	M-A	*	*	3	*	3	3	*	7	*	*	*
dibenz[a,h]acridine	226-36-8											
dibenz[a,j]acridine	224-42-0											
dibenzo[e,i]pyrene	189-55-9											
7H-dibenzo[c,g]carbazole	194-59-2											
7,12-dimethylbenz[a]anthracene	57-97-6	*	*	*	*	*	*	*	*	2	*	*
1,8-dinitropyrene	42397-65-9											
1,4-dioxane	123-91-1											
1,2-diphenylhydrazine	122-66-7											
ethylene dibromide	106-93-4											
hexachlorocyclopentadiene	77-47-4											
indeno[1,2,3-cd]pyrene	193-39-5											
lead	7439-92-1											
pyrene	129-00-0	M-A	*	*	7	*	*	2	*	7	7	*	3
silver (ionic form)	7440-22-4											
styrene	100-42-5	M-A	*	*	3	*	*	3	*	7	*	*	*
2,3,4,6-tetrachlorophenol	58-90-2											
tetraethyllead	78-00-2											
thiourea	62-56-6											
uranium	7440-61-1											
zinc	7440-66-6	M-A	0	*	2	3	*	2	*	7	*	*	*

Score Types: 0 - data did not precisely match criteria, or method was unusual
W - worst-case basis
E - estimated by model or analogy
L - limited data set

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SECONDARY LIST, GROUP 'B': Persistent AND Bioaccumulative AND Noncancer Toxicity Score 8

Substance Name	CAS Number	PERS SUM	PERS AIR	PERS AQ	PERS SOI	PERS SED	BIOCONC	ACU SUM	ACU INHL	ACU DERM	ACU AQUA	ACU ORAL	NONM SUM	NONM AQU	NONM TER	PHYT SUM	PHYT AQU	PHYT TER	SUBLETHAL MAML	SUBLETHAL NAML	SUBLETHAL NAML	TERATOG	CARCIN	MICHIGAN CERPS	MICHIGAN CERFG	DHR CCHR	DHR CCHR	CHR SCORES CCHR	CHR SCORES CACU	CHR SCORES CACU	CHR SCORES CACR	CHR SCORES CGEN	CHR SCORES CREPRO	IARC GROUP
aluminum	7429-90-5	10	10	10	10	10	7	8					60			60			60			2	*										
chlorobenzene	108-90-7	4	0	0	10U		7	8U			8U		2			2			*			*	10L										
hexachlorobutadiene	87-68-3	10E	10E	10E	10E		10	8			8		8	8										*	*	1	7	1	*	*	7	3	*	*	
hexachloroethane	67-72-1	10	10	0	10L		7	8	*	0	8	2	2L	*		2	2	*	8	4	8	0	10L	*	2	2	7	*	2	1	7	3	*	*	3
pentachlorobenzene	608-93-5	10	10E	10E	10		7	8			8		6L			*			*			4	*											3
2,4,5-trichlorophenol	95-95-4	100	0	0	100	4	7	8	*	*	8	2	*	*	*	4L	4L	*	4	*	4	0L	4L											
triphenyl phosphate	115-86-6	7L	*	0	7L	7L	4	8			8													0-U	3	2	2	*	2	1	0	7	*	*	*

Score Tags: G - data did not precisely match criteria, or method was unusual
U - worst-case basis
E - estimated by model or analogy
L - limited data set

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[illegible] Table 4-4 Correlation of Bioaccumulative and Nonbioaccumulative Toxicity Score B

Substance Name	CAS Number	PERSSUM	PERSAIR	PERSAQ.	PERSSOI	PERSSED	BIOCONC.	ACUSUM.	ACUINHL	ACUDERM	ACUAQUA	ACUORAL	NONHSUM	NONHSAQU	NONHTER	PHYTSUM	PHYTSAQU	PHYTTER	SUBLETHAL MAMMAL SUM	SUBLETHAL MAMMAL INH	SUBLETHAL MAMMAL ORL	TERATOGM	CARCINOGEN.	MICHIGAN CHR SCORES CCPER	CCBLFG	CCONRPT	CCHRTRQ	CCHAPLR	CCACUPOR	CCACUDR	CCACUAQ	CCACUINH	CCGENTOX	CCREPRO.	IAR GRO
4-chlorophenyl phenyl ether (1-chloro-4-phenoxyben	7005-72-3	0E		0E			7	8			8																							
palustric acid	1945-53-5	*	*	*	*		10L	8L	*	*	8L	*	*	*	*	*	*	*	*	*	*	*	*	*	2	*	*	*	*	7	*	*	*	
selenium	7782-49-2	10	10	10	10	10	*	10W			10W											6		H-A	*	*	3	*	*	2	*	2	7	*	7	3
1,2,3,5-tetrachlorobenzene	634-90-2						7	8W			8W		*			4			8Q			*	*												
tetrachloroguaiacol	2539-17-5						7	8			8		*			*			*			*	*												
2,3,4,5-tetrachlorophenol	4901-51-3						7L	8			8		*			*			*			*	*												
1,2,3-trichlorobenzene	87-61-6	*	*	*	*		7	8			8		8	8										*	2	*	2	7	2	*	*	7	*	*	*	
trixylyl phosphate	25155-23-1	*					7L	8W			8W	0	0L	0L	*	4U	4U	*	*	*	*	*	*												

Score Legend: A - data did not precisely match criteria, or method was unusual
W - worst-case basis
E - estimated by model or analogy
L - limited data set

Appendix 'C'

Evaluation of Environmental Impacts/Use Impairments Associated With Substances on the Primary List of Candidate Substances for Bans or Phase-Outs

The following contaminant-specific discussions highlight the maximum concentrations detected in water, sediment and biological organisms from various locations in the Great Lakes Basin. It must be emphasized, however, that concentrations in each area can span a wide range, from 'non-detected' to levels exceeding criteria.

Anthracene

As with the other PAH compounds considered in this section, anthracene is a by-product of the combustion of fossil fuels, such as: forest fires; heat and power generation; and internal combustion engines. Major industrial sources include coal tar processing, petroleum refining, shale refining, coal, coke and kerosene processing. Many of these compounds are also present in asphalt or bitumen (deBarros, 1984; Verschueren, 1983).

There are presently no criteria for this PAH compound regarding allowable or safe concentrations in receiving waters, sediment or aquatic biota. However, the GLWQA states that: "For other contaminants for which Specific Objectives have not been defined, but which can be demonstrated to be persistent and are likely to be toxic, the concentration of such compounds in water or aquatic organisms should be substantially absent, i.e., less than detection levels as determined by the best scientific methodology available" (IJC, 1987). Monitoring has detected elevated concentrations (i.e., above background or control) of anthracene in samples collected near or downstream of Ontario discharges and previous coal gasification sites, particularly in industrialized urban areas. Consequently, there are impairments in a number of Great Lakes Areas of Concern. Furthermore, sediments in some areas exceed the proposed OMOE sediment quality guideline for 'total PAHs' (Tables 2.4 and 2.5). For example, along the Ontario shore of the St. Marys River, whole water samples contained up to 173 ng/l in 1986 (UGLCCS, 1988). Levels of anthracene in the Detroit River downstream of Turkey Creek were 2 ng/l in 1987 (Cowell, 1990).

Anthracene is also adsorbed to fine particulate material. For example, up to 2.44 mg/kg (on a dry weight basis) of anthracene were associated with the suspended sediment (particulate) phase of St. Marys River water (UGLCCS, 1988).

Concentrations in surficial (recent) sediments were up to 4.32 mg/kg (dry weight basis) in Thunder Bay Harbour (EC, 1988), 6.07 mg/kg in the St. Marys River (Kauss, 1991), 2.84 mg/kg in the St. Clair River (OMOE, unpublished 1990 data), 5.50 mg/kg in Ashbridges Bay, Toronto (Jaagumagi et al., 1991d), 6.20 mg/kg in the Bay of Quinte (Poulton, 1990), and 4.02 mg/kg in the St. Lawrence River (Jaagumagi and Persaud, 1992). Concentrations up to 88.1 mg/kg were found in an area of Hamilton Harbour contaminated with coal tar (Murphy et al., 1990). All of these maxima

exceed the proposed OMOE 'lowest effect level' sediment quality guideline of 2 mg/kg for 'total PAHs'. This causes concern over anthracene toxicity to the more sensitive species of sediment-dwelling organisms and its possible biomagnification in the food chain (Persaud et al., 1991).

Fewer data are available on anthracene concentrations in biota. This PAH has not been detected in young-of-the-year fish samples from a number of Great Lakes sampling sites (Suns et al., 1991), or in adult sport fish from the St. Marys River and the lower Niagara River (OMOE, unpublished 1989 data). Nevertheless, it was accumulated to detectable levels by benthic invertebrates such as freshwater mussels. In 1985, after three weeks of exposure in the St. Marys River in cages, mussels at Ontario stations contained up to 0.123 mg/kg on a wet weight basis (Kauss and Hamdy, 1991). After 18 weeks in the St. Clair and Detroit Rivers, mussels contained up to 0.028 mg/kg and 0.011 mg/kg, respectively (OMOE, unpublished 1984 data).

Arsenic

Arsenic is a constituent of non-ferrous metal ores and is used in: the smelting and refining of gold, zinc, lead, copper, silver and nickel; and the manufacture and production of glass, cloth, electrical semi-conductors, detergents and commercial grade sulphuric acid. It is also used in pesticides and fertilizers (deBarros, 1984).

Concentrations of arsenic in sediment exceed Ontario (OMOE) dredging and sediment quality guidelines in a number of areas in the Great Lakes Basin. Although objectives exist for water quality (Table 2.4), there is no available criterion for safe concentrations of arsenic in aquatic biota.

Concentrations of arsenic in whole water normally do not exceed available criteria. For example, the median dissolved and particulate-associated levels for the Great Lakes were 0.520 ug/l and 0.010 ug/l in Lake Superior, 0.250 ug/l and 0.0086 ug/l in Lake Huron, 0.420 ug/l and 0.087 ug/l in Lake Erie and 0.490 ug/l, and 0.024 ug/l in Lake Ontario (Rossman and Barres, 1988). The maximum whole water concentration recorded during a survey of Ontario tributaries discharging to the St. Clair River, Lake St. Clair and the Detroit River was 5 ug/l (Johnson and Kauss, 1991). Other maxima include 15 ug/l in Collingwood Harbour, 6 ug/l in the Bay of Quinte and 2 ug/l in Toronto Harbour (Jaagumagi and Persaud, 1992). Nevertheless, when coupled with a large flow, even very low concentrations can result in a substantial loading, as in the Niagara River during the period 1986-1987: a difference of 0.14 ug/l in whole water arsenic concentration between the head (Fort Erie) and the mouth of the river (Niagara-on-the-Lake) resulted in a significant increase in the daily loading (0.101 tonnes/d) from the river to Lake Ontario (Niagara River Data Interpretation Group, 1988). Exceedances of the PWQO of 100 ug/l for the protection of aquatic life or the GLWQA specific objective of 50 ug/l for the protection of raw water supplies occurred in the Moira, Montreal and English Rivers, and in Farr Creek (OMOE, 1991a). In addition, some Ontario mining operations exceed the Ministry's effluent guidelines or requirements regarding arsenic discharges (OMOE, 1991b).

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Elevated concentrations of arsenic can be associated with the suspended sediment fraction of water. For example, up to 13.10 mg/kg (dry weight) arsenic were detected in this phase in Thunder Bay Harbour (Boyd, 1990), up to 13.00 mg/kg in Toronto's Mimico Creek (Boyd, 1988), and up to 8.10 mg/kg in the St. Lawrence River near Cornwall (OMOE and EC, 1990). In the previously-noted tributary survey, a maximum of 35.69 mg/kg was found in a sample from the Belle River, a Lake St. Clair tributary (Johnson and Kauss, 1991).

Based on exceedances of guidelines, impairment of sediment quality by arsenic exists in many Areas of Concern and in bays and rivers in the Great Lakes Basin (Tables 2.4 and 2.5). For example, surficial sediments contained up to 10.50 mg/kg (dry weight) in Thunder Bay (Boyd, 1990), 16.00 mg/kg in Nipigon Bay (OMOE, EC, OMNR and F&OC, 1991a), 8.50 mg/kg in Jackfish Bay (Beak, 1988b), 30.00 mg/kg in the St. Marys River (Jaagumagi et al., 1991c), 6.76 mg/kg in Penetang Harbour (Jaagumagi, 1988), 16.71 mg/kg in the St. Clair River (OMOE and MDNR, 1991), 12.50 mg/kg in the Detroit River (Jaagumagi, 1988), 22.3 mg/kg in Muddy Creek, which discharges to Wheatly Harbour (OMOE, EC, OMNR and OMAF, 1991), 12.68 mg/kg in the Niagara River (Creese, 1987), 6.68 mg/kg in Port Weller Harbour (Jaagumagi, 1988), 46.00 mg/kg in Hamilton Harbour (OMOE, OMNR, OMAF, EC, FOC and RBG, 1989), 6.47 mg/kg in Oakville Harbour (Jaagumagi, 1988), 11.70 mg/kg, 10.52 mg/kg, 15.10 mg/kg, 12.12 mg/kg and 7.63 mg/kg in Toronto's Humber Bay, inner Harbour, Ashbridges Bay, East Headland and Bluffer's Park, respectively (Jaagumagi, 1988; Jaagumagi et al., 1991d), 16.10 mg/kg in Frenchman's Bay (Jaagumagi and Persaud, 1992), 16.00 mg/kg in the Bay of Quinte (Jaagumagi, 1988), and 6.96 mg/kg in the St. Lawrence River near Cornwall (OMOE and EC 1990). Most of these values exceed both the present OMOE open water disposal guideline of 8 mg/kg as well as the proposed 'lowest effect level' sediment quality guideline of 6 mg/kg. With respect to the latter guideline, there is consequently concern regarding arsenic toxicity to more sensitive species of sediment-dwelling organisms and the possibility of its biomagnification up through the food chain (Persaud et al., 1991). Furthermore, maximum levels of 77.40 mg/kg in the St. Marys River (Hesselberg and Hamdy, 1987), 460 mg/kg in Port Hope Harbour (EC and OMOE, 1990) and 44.36 mg/kg in the St. Lawrence River near Maitland (Wilkins, 1988) exceed the proposed OMOE 'severe effect level' guideline of 33 mg/kg, a level above which pronounced disturbance of the sediment-dwelling community can be expected (Persaud et al., 1991).

Concentrations of arsenic in the filamentous alga Cladophora ranged up to 15.25 mg/kg (dry weight) along the Ontario shore of the Niagara River (OMOE, EC, OMNR and F&OC, 1991), approximately double the maximum of 7.90 mg/kg reported for Wheatly Harbour (OMOE, EC, OMNR and OMAF, 1991). Mean concentrations of arsenic in aquatic macrophytes from the Bay of Quinte varied with species and location, with a maximum of 6.8 mg/kg in Vallisneria americana from the Belleville area (Poulton, 1990). Oligochaetes (sludge worms) from Toronto's Eastern Headland and Humber Bay sediments contained up to 0.60 mg/kg (wet weight) of arsenic (EC, OMOE, OMNR and MTRCA, 1989). Oligochaetes contained up to 9.74 mg/kg in the St Marys River (Jaagumagi et al., 1991c), 1.88 mg/kg in Canagagigue Creek (Jaagumagi et al., 1991a), 2.21 mg/kg in the Grand River (Jaagumagi et al., 1991b) and 4.13 mg/kg in Toronto (Jaagumagi et al., 1991d).

Oligochaetes, chironomids and amphipods from Collingwood Harbour sediments contained up to 1.76 mg/kg, 0.88 mg/kg and 0.75 mg/kg, respectively, of arsenic (OMOE and EC, 1989). Concentrations accumulated by mussels after as much as 101 days of exposure in the Niagara River (up to 1.3 mg/kg) were still only slightly higher than the pre-exposure level of 0.7 mg/kg (Kauss and Angelow, 1988). In laboratory bioassays, burrowing mayfly larvae and fathead minnows exposed to contaminated Hamilton Harbour sediments accumulated up to 9.71 mg/kg and 1.00 mg/kg of arsenic respectively (Krantzberg,1991). The maximum arsenic concentration in fathead minnows after their exposure to Wheatly Harbour sediments was 0.14 mg/kg, in contrast to 0.07 mg/kg in controls (OMOE, EC, OMNR and OMAF, 1991).

Adult sculpin (a bottom-dwelling fish) from Collingwood Harbour contained up to 0.07 mg/kg (wet weight) of arsenic (OMOE and EC, 1989), whereas they contained up to 0.91 mg/kg in the St. Marys River (Jaagumagi et al., 1991c) and 1.53 mg/kg in Toronto (Jaagumagi et al., 1991c). Arsenic levels of up to 0.39 mg/kg have been reported for adult walleye from Adolphus Reach in the Bay of Quinte (Poulton, 1990).

Benzo[a]pyrene

Concentrations of benzo[a]pyrene exceeded criteria for sediments (Table 2.4) in a number of Ontario Great Lakes Areas of Concern, particularly in industrialized urban areas (Table 2.5).
In the St. Marys River, whole water samples contained up to 140 ng/l (estimated) (UGLCCS, 1988), which is above the recommended IJC objective of 10 ng/l for the protection of aquatic life. In Turkey Creek, a tributary of the Detroit River, the concentration in water was 10 ng/l (Cowell, 1990). The mean 'recombined whole water' benzo[a]pyrene concentration at Niagara-on-the-Lake was 1.59 ng/l during the period 1986-1987 (Niagara River Data Interpretation Group, 1988).

Up to 3.88 mg/kg (dry weight) were associated with the suspended sediment phase of water in the St. Marys River (UGLCCS, 1988). In the Niagara River, the 0.993 kg/d increase in the suspended sediment-associated daily loading between Fort Erie and Niagara-on-the-Lake was significant (Niagara River Data Interpretation Group, 1988).

Concentrations of benzo[a]pyrene in surficial sediments ranged up to 5.79 mg/kg (dry weight) in the St. Marys River (Kauss, 1992), 2.99 mg/kg in the St. Clair River (OMOE, unpublished 1990 data), 1.73 mg/kg in the Grand River at Kitchener-Waterloo (Jaagumagi et al., 1991b), 40.2 mg/kg in Kettle Creek which discharges to eastern Lake Erie (Griffiths, 1988), 69.2 mg/kg in Hamilton Harbour (Murphy et al., 1990), 4.30 mg/kg in Toronto's Ashbridges Bay (Jaagumagi et al., 1991d), 2.47 mg/kg in Rice Lake (Jaagumagi and Persaud, 1992), 1.70 mg/kg in the Bay of Quinte (Poulton, 1990) and 5.68 mg/kg in the St. Lawrence River (Jaagumagi and Persaud, 1992). Many of these maxima exceed the proposed OMOE 'lowest effect level' sediment quality guideline of 2 mg/kg for 'total PAHs', and therefore there is concern over toxicity of this compound to the more sensitive species of

sediment-dwelling organisms and its possible biomagnification in the food chain (Persaud et al., 1991).

Benzo[a]pyrene is accumulated by some aquatic invertebrate species. For example, maximum concentrations in caged mussels were 0.013 mg/kg (wet weight) in caged mussels exposed in the St. Marys River (Kauss and Hamdy, 1991), 0.020 mg/kg in the St. Clair River, 0.027 mg/kg in the Detroit River (OMOE, unpublished 1984 data) and 0.039 mg/kg in Chippawa Creek, a tributary of the Niagara River (Anderson et al., 1991). These levels are below the recommended IJC objective of 1.000 mg/kg for the protection of higher trophic levels. In contrast, burrowing mayfly larvae and fathead minnows exposed to contaminated Hamilton Harbour sediments under laboratory conditions accumulated up to 1.572 mg/kg and 0.209 mg/kg, respectively (Krantzberg, 1991), the former being above the IJC objective. This PAH has not been detected in young-of-the-year fish samples from the Great Lakes (Suns et al., 1991), or in adult sport fish from the St. Marys River and the lower Niagara River (OMOE, unpublished 1989 data).

Benzo[g,h,i]perylene

Concentrations of benzo[g,h,i]perylene exceed the proposed OMOE sediment criterion for 'total PAHs'. Although there are presently no numerical criteria for safe concentrations of this compound in ambient water or aquatic biota, elevated concentrations have been detected in samples collected near or downstream of Ontario discharges in industrialized urban areas. The GLWQA states that such contaminants should not be detectable in water or aquatic organisms (IJC, 1987).

In the St. Marys River, whole water samples contained up to 29 ng/l of this PAH and up to 0.822 mg/kg (dry weight) was associated with the suspended sediment phase (UGLCCS, 1988).

Concentrations of this compound in surficial sediments ranged up to 1.76 mg/kg (dry weight) in Thunder Bay Harbour (EC, 1988), 3.85 mg/kg in the St. Marys River (Kauss, 1992), 1.15 mg/kg in the St. Clair River (OMOE, unpublished 1990 data), 60.6 mg/kg in Hamilton Harbour (Murphy et al., 1990) and 1.62 mg/kg in Rice Lake (Jaagumagi and Persaud, 1992). Some of these values exceed the proposed OMOE 'lowest effect level' sediment quality guideline of 2 mg/kg for 'total PAHs'. Consequently, there is concern over benzo[g,h,i]perylene toxicity to the more sensitive species of sediment-dwelling organisms and its possible biomagnification in the food chain (Persaud et al., 1991).

Low concentrations of benzo[g,h,i]perylene have been found in some aquatic species. Maximum concentrations were 0.001 mg/kg (wet weight) in caged mussels exposed in the St. Marys River (Kauss and Hamdy, 1991) and 0.003 mg/kg in the St. Clair River (OMOE, unpublished 1984 data). In contrast, burrowing mayfly larvae and fathead minnows exposed to contaminated Hamilton Harbour sediments accumulated up to 0.350 mg/kg and 0.062 mg/kg, respectively (Krantzberg, 1991). This PAH has not been detected in young-of-the-year fish samples from a number of Great Lakes

sampling sites (Suns et al., 1991), or in adult sport fish from the St. Marys River and the lower Niagara River (OMOE, unpublished 1989 data).

Benz[a]anthracene

Concentrations of benz[a]anthracene in some sediments exceed the proposed OMOE sediment criterion for 'total PAHs'. Elevated levels of this PAH compound have been found in water samples collected near or downstream of Ontario discharges, particularly in urban areas. At present, there are no criteria for safe concentrations of this aromatic compound in ambient water or aquatic biota. However, the GLWQA states that such contaminants should not be detectable in water or aquatic organisms (IJC, 1987).

In the St. Marys River, whole water samples contained up to 286 ng/l (UGLCCS, 1988). In the Niagara River, the mean 'recombined whole water' benz[a]anthracene concentration at Niagara-on-the-Lake was 2.58 ng/l (Niagara River Data Interpretation Group, 1988).

High concentrations of benz[a]anthracene can be associated with the suspended sediment phase of water. In the St. Marys River, up to 7.684 mg/kg (dry weight) were detected in this phase (UGLCCS, 1988).

Concentrations of this PAH in surficial sediments ranged up to 3.68 mg/kg (dry weight) in Thunder Bay Harbour (E C, 1988), 9.74 mg/kg in the St. Marys River (Kauss, 1992), 4.93 mg/kg in the St. Clair River (OMOE, unpublished 1990 data), 102.0 mg/kg in Hamilton Harbour (Murphy et al., 1990), 4.90 mg/kg in Toronto's Ashbridges Bay (Jaagumagi and Persaud, 1992), 2.90 mg/kg in Rice Lake (Jaagumagi and Persaud, 1992), 3.20 mg/kg in the Bay of Quinte (Poulton, 1990) and 10.10 mg/kg in the St. Lawrence River (Jaagumagi and Persaud, 1992). These maxima are all above the proposed OMOE 'lowest effect level' sediment quality guideline of 2 mg/kg for 'total PAHs', and therefore there is concern over benz[a]anthracene toxicity to the more sensitive species of sediment-dwelling organisms and its possible biomagnification in the food chain (Persaud et al., 1991).

Elevated (above background or control) concentrations of benz[a]anthracene have been detected in some aquatic invertebrates. For example, freshwater mussels exposed in Chippawa Creek, an Ontario tributary to the Niagara River, contained 0.036 mg/kg (wet weight) after three weeks (Anderson et al., 1991). Burrowing mayfly larvae and fathead minnows exposed to sediments from Wheatly Harbour and from Muddy Creek (a tributary of Wheatly Harbour) accumulated up to 0.097 mg/kg and 0.385 mg/kg, respectively (OMOE, EC, OMNR and OMAF, 1991). Burrowing mayfly larvae and fathead minnows exposed to contaminated Hamilton Harbour sediments accumulated up to 4.310 mg/kg and 0.400 mg/kg, respectively (Krantzberg, 1991). Although this PAH has not been detected in young-of-the-year fish samples from the Great Lakes (Suns et al., 1991), it has been detected at concentrations close to the detection level of 0.005 mg/kg in some samples of adult sport fish. In the St. Marys River, the maximum benz[a]anthracene concentrations in walleye, chinook salmon and pink salmon were 0.010 mg/kg, 0.008 mg/kg and 'not

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detected', respectively; it was not detected in fish from the lower Niagara River (OMOE, unpublished 1989 data).

1,4-Dichlorobenzene (Paradichlorobenzene)

This volatile organochlorine is used as a soil fumigant and pesticide, as well as in the manufacture of: moth repellants; air deodorizers; dyes and their intermediates; and pharmaceuticals (Verschueren, 1983).

Concentrations in water do not currently exceed available criteria (Tables 2.4 and 2.5). There are presently no criteria for safe concentrations in sediment or aquatic biota.

Lakewide mean concentrations of 1,4-dichlorobenzene in water increased from the upper to the lower Great Lakes in 1986: i.e., 0.332 ng/l in Lake Superior, 0.284 ng/l in Lake Huron and 0.377 ng/l in Georgian Bay, in contrast to 0.994 ng/l in Lake Erie and 1.462 ng/l in Lake Ontario (IJC, 1989). Still higher levels have been detected in nearshore areas, such as up to 42 ng/l downstream of a wastewater treatment plant in the Grand River (Oliver and Nicol, 1982). Although the mean concentration difference between the head and the mouth of the Niagara River in the dissolved and suspended sediment phases was only 1.6511 ng/l and 0.1812 ng/l (equivalent water concentration), respectively, this resulted in a significant increase between the inlet and outlet of the river in both the dissolved (1.0321 kg/d) and suspended sediment-associated (0.113 kg/d) daily loadings of 1,4-dichlorobenzene (Niagara River Data Interpretation Group, 1988).

Open lake mean surficial sediment concentrations of 1,4-dichlorobenzene also exhibit a major increase from the upper Great Lakes to Lake Ontario: i.e., 0.005 mg/kg (dry weight) in Lake Superior, 0.016 mg/kg in Lake Huron, 0.009 mg/kg in Lake Erie and 0.094 mg/kg in Lake Ontario. Maximum concentrations in Lake Superior and Lake Ontario were 0.009 mg/kg and 0.210 mg/kg, respectively (Oliver and Nicol, 1982).

Data on the concentrations of 1,4-dichlorobenzene in aquatic biota are relatively scarce. Phytoplankton from the nearshore of the upper St. Clair River contained up to 1600 mg/kg (dry weight) (OMOE and MDNR, 1991). Single samples of lake or rainbow trout from each of the Ontario Great Lakes contained low concentrations of 1,4-dichlorobenzene, ranging from "not detected' in Lake Superior to 0.004 mg/kg (wet weight) in Lakes Erie and Ontario (Oliver and Nicol, 1982).

3,3'-Dichlorobenzidine

This compound, also known as 3,3'-dichloro-4,4'-diaminobiphenyl, is used as: an intermediate in the manufacture of azo pigments;a curing agent for isocyanate-terminated resins; and for urethane resins (Verschueren, 1983).

There are no available criteria for safe concentrations of this organic compound in receiving water, sediment or aquatic biota. More importantly, the current lack of OMOE analytical methods for these matrices or for effluents precludes the ability to

determine loadings of this compound or its environmental distribution and impact at this time.

Hexachlorobenzene

In Ontario, hexachlorobenzene contamination is perhaps largely a byproduct of the electrolytic production of chlorine and of certain chlorinated solvents (Kauss and Hamdy, 1985). However, this chlorinated aromatic compound has also been used as: a fungicide for seed treatment of cereal grains prior to planting; as a wood preservative; in fluorocarbon and synthetic rubber production; a plasticizer for polyvinyl chloride; in the manufacture of pyrotechnics; and as a fluxing agent in aluminum smelting. Other possible sources of contamination are related to its creation as a byproduct during the manufacture of vinyl chloride monomer, certain pesticides such as atrazine and pentachlorophenol, and of sodium chlorate (debarros, 1984; Verschueren, 1983).

This contaminant has been detected in water, sediment or biota samples from most Great Lakes Areas of Concern. Concentrations in some samples exceed available criteria for these components of the aquatic ecosystem (Tables 2.4 and 2.5).

Lakewide mean concentrations of hexachlorobenzene in water increase gradually as one progresses down through the Great Lakes: 0.025 ng/l in Lake Superior, 0.029 ng/l in Lake Huron, 0.041 ng/l in Georgian Bay, 0.054 ng/l in Lake Erie, and 0.057 ng/l in Lake Ontario (IJC, 1989). While these average levels do not exceed the PWQO of 6.5 ng/l for the protection of aquatic life, concentrations in some nearshore Areas of Concern do. These include the maxima of 8 ng/l in Thunder Bay and 7 ng/l in Toronto Harbour (Jaagumagi and Persaud, 1992). Although 1984 concentrations along the Sarnia shore of the St. Clair River reached as high as 2400 ng/l, more recent (1986) concentrations in water have been lower, with a maximum of 210 ng/l being reported (OMOE and MDNR, 1991). Nevertheless, the latter is still well above the PWQO. Lower levels of 0.31 to 0.33 ng/l were found in the Detroit River in 1986 (MDNR and OMOE, 1991). In the Niagara River, hexachlorobenzene was detected in the dissolved phase at Niagara-on-the-Lake at a mean concentration of 0.1202 ng/l, but not at Fort Erie. This resulted in a significant increase between the head and the mouth of the river in the daily loading (0.075 kg/d) of this compound (Niagara River Data Interpretation Group, 1988).

Elevated levels of hexachlorobenzene have also been detected in the suspended sediment fraction of water near or downstream of sources. In the St. Clair and Detroit Rivers, maximum concentrations in this phase were 0.535 mg/kg and 0.019 mg/kg (dry weight), respectively. Based on these 1984 data, the estimated net daily loading increase between the head and the mouth of the St. Clair River was 0.780 kg/d, and 0.204 kg/d for the Detroit River (Johnson and Kauss, 1987). In the Niagara River, the significant sediment-associated loading increase of 0.104 kg/d between the head and the mouth was related to a concentration difference of only 0.1661 ng/l (equivalent water concentration) (Niagara River Data Interpretation Group, 1988). In the Toronto area, a maximum of 0.027 mg/kg was detected in the

Don River, a tributary of Lake Ontario (Boyd, 1988). Lake Ontario suspended sediment samples contained a mean concentration of 0.014 mg/kg (Oliver, 1984).

Mean open lake surficial sediment concentrations of hexachlorobenzene also exhibit a major increase from the upper Great Lakes to Lake Ontario: i.e., 0.0002 mg/kg (dry weight) in Lake Superior, 0.002 mg/kg in Lake Huron, 0.003 mg/kg in Lake Erie and 0.097 mg/kg in Lake Ontario. Maximum concentrations in Lake Superior and Lake Ontario were 0.0007 mg/kg and 0.320 mg/kg, respectively (Oliver and Nicol, 1982). Maximum concentrations in a number of waterbodies are below the proposed OMOE 'no effect level' sediment quality guideline of 0.01 mg/kg. These include Lakes Superior, Huron and Erie and such areas of concern as Thunder Bay with 0.005 mg/kg (Boyd, 1990), and Hamilton Harbour with 0.007 mg/kg (OMOE, OMNR, OMAF, EC, FOC and RBG, 1989). Concentrations in other areas, such as the mean in Lake Ontario (see above), and the maxima of 0.034 mg/kg in Peninsula Harbour (Jardine and Simpson, 1990), 0.047 mg/kg in Collingwood Harbour (Jaagumagi and Persaud, 1992), 0.028 mg/kg in the Detroit River (Thornley and Hamdy, 1984), 0.076 mg/kg in the Niagara River (Creese, 1987), and 0.590 mg/kg in the Bay of Quinte (Poulton, 1990) exceed the proposed OMOE 'lowest effect level' sediment quality guideline of 0.02 mg/kg. Consequently, there is concern regarding hexachlorobenzene toxicity to the more sensitive species of sediment-dwelling organisms and its possible biomagnification up through the food chain. Furthermore, sediments from some sampling locations downstream of known sources contain hexachlorobenzene levels exceeding the proposed OMOE 'severe effect level' sediment quality guideline (Table 2.4), a level above which pronounced disturbance of the sediment-dwelling community can be expected (Persaud et al., 1991). These include the St. Clair River, with levels up to 3.28 mg/kg in 1985 (OMOE and MDNR, 1991) and up to 45.50 mg/kg in 1990 (OMOE, unpublished 1990 data) and the St. Lawrence River near Maitland, with up to 0.351 mg/kg (Wilkins, 1988).

Phytoplankton collected near Sarnia organic chemical industry discharges to the St. Clair River contained up to 2700 mg/kg (dry weight) of hexachlorobenzene (OMOE and MDNR, 1991). Mean concentrations in Cladophora from the river ranged up to 0.050 mg/kg; mean concentrations in aquatic macrophytes from the river varied with species and location, with a maximum of 0.038 mg/kg in the macrophyte Potamogeton gramineus (St. Clair River MISA Pilot Site Team, 1991). Oligochaetes from Toronto's Eastern Waterfront sediments contained up to 0.070 mg/kg (wet weight) of hexachlorobenzene (EC, OMOE, OMNR and MTRCA, 1989). The highest concentrations accumulated by caged freshwater mussels exposed along the Ontario shore of St. Clair River in 1984 were 0.551 mg/kg (wet weight) (OMOE and MDNR, 1991), and 0.004 mg/kg in the Detroit River (OMOE, unpublished 1984 data). In 1986, the maximum hexachlorobenzene level accumulated by caged mussels in the St. Clair River was 0.035 mg/kg (OMOE and MDNR, 1991). Concentrations in native burrowing mayfly larvae from the same river ranged up to 0.126 mg/kg (dry weight) and were positively correlated to levels in the sediment (OMOE and MDNR, 1991). Emergent (adult) caddisflies or mayflies contained up to 0.222 mg/kg (dry weight) in the St. Clair River and 0.120 mg/kg in the Detroit River, compared to 0.0008 mg/kg to 0.0019 mg/kg in inland waters (Ciborowski and Corkum, 1988; Kovats and Ciborowski, 1989).

Except for locations close to sources, concentrations of hexachlorobenzene in young-of-the-year spottail shiners are normally low or non-detectable. This is shown by recent (1985-1988) data from numerous nearshore collection sites in the Great Lakes. The maximum mean concentration at any Ontario site in Lake Superior was 0.004 mg/kg (wet weight), 'not detected' in the St. Marys River, 0.005 mg/kg in Lake Huron, 0.060 mg/kg in the St. Clair River, 0.010 mg/kg in Lake St. Clair, 0.011 mg/kg in the Detroit River, 0.004 mg/kg in Lake Erie, 0.004 mg/kg in the Niagara River, 0.010 mg/kg in Lake Ontario and 0.005 mg/kg in the St. Lawrence River. While these are all below the New York State criterion of 0.33 mg/kg for the protection of fish-eating birds, a concentration of 0.780 mg/kg was detected near a source along the U.S. side of the Niagara River in 1984 (Suns et al., 1991). Concentrations of hexachlorobenzene in sculpin from the St. Clair River ranged up to 0.018 mg/kg (wet weight), in contrast to the maximum of 0.003 mg/kg in sculpin from the control location (OMOE and MDNR, 1991). Sculpin from Collingwood Harbour contained up to 0.010 mg/kg (OMOE and EC, 1989).

Presently, there is no federal human consumption guideline for fish; however, the USEPA has established a draft guideline of 0.0064 mg/kg for hexachlorobenzene. Mean concentrations in dorsal fillets of channel catfish from Lake Huron slightly exceeded this value during 1984 and 1985, whereas Lake St. Clair catfish greatly exceeded this value during the period 1979 to 1986 (OMOE and MDNR, 1991).

Detectable levels of hexachlorobenzene are also present in the higher trophic levels of the Great Lakes ecosystem. These include waterfowl, piscivorous birds and snapping turtles (Allan et al., 1991). For example, mean concentrations in the breast muscle of non-migratory mallard and redhead ducks from Walpole Island in the lower St. Clair River (0.007 mg/kg and 0.011 mg/kg, respectively) were higher than in the corresponding migratory duck samples (0.005 mg/kg and 0.002 mg/kg, respectively) (OMOE and MDNR, 1991).

alpha-1,2,3,4,5,6-Hexachlorocyclohexane

This organochlorine contaminant is also known as alpha-BHC and is a constituent of technical grade BHC. Technical grade BHC contains a mixture of alpha, beta, gamma (lindane), delta and epsilon isomers in the amounts of about 5:0.5:1:0.25:trace (deBarros, 1984).

Water and sediments in some areas exceeded available criteria (Tables 2.4 and 2.5). There are presently no numerical criteria for safe concentrations of alpha-BHC in aquatic biota. However, the GLWQA states that contaminants such as this should not be detectable (IJC, 1987).

The alpha isomer is considered to be ubiquitous in Great Lakes Basin waters. During the period 1984-1988, alpha-BHC was detected at 55 of 66 river and stream monitoring sites in Ontario, and 48% of the samples contained concentrations above the 1 ng/l analytical method minimum reporting limit (Whitehead, 1991). Mean concentrations in the Great Lakes range from 3.823 ng/l in Lake Erie to 7.840 ng/l in Lake Superior (IJC, 1989). Concentrations in the dissolved phase of water samples

from the St. Clair River were similar, with a range of 'not detected' to 6.650 ng/l (OMOE and MDNR, 1991). At the outlet of Lake Ontario to the St. Lawrence River, mean concentrations in water during 1987 ranged from 2.76 ng/l north of, to 3.70 ng/l south of Wolfe Island (Tsanis et al., 1989).

Locally elevated concentrations in water samples of up to 21 ng/l and 159 ng/l, respectively, have been detected in Peninsula Harbour (Jardine and Simpson, 1990) and in the Niagara River near U.S. sources of contamination (MOE, unpublished 1983 data). These values exceed the NYSDEC ambient water quality criterion of 10 ng/L for the protection of aquatic life. Elevated concentrations have also been detected in the effluents of municipal sewage treatment plants (up to 100 ng/l) and of some industries (up to 30 ng/l) discharging to the Bay of Quinte area (Poulton, 1990).

In the Niagara River, the mean suspended sediment-associated loading of 0.014 kg/d increased significantly between Fort Erie and Niagara-on-the-Lake during the period 1986-1987, and was due to a concentration difference of 0.0225 ng/l (equivalent water concentration) (Niagara River Data Interpretation Group, 1988). In the Toronto area, the maximum of 0.017 mg/kg (dry weight) on suspended sediments was detected in Mimico Creek, a tributary of Lake Ontario (Boyd, 1988).

Surficial sediment levels of this organochlorine, when detected, are normally quite low, and near or below the proposed OMOE 'lowest effect level' sediment quality guideline of 0.006 mg/kg. For example, maximum concentrations were 0.001 mg/kg (dry weight) in Thunder Bay (Boyd, 1990), 0.002 mg/kg in Peninsula Harbour (Jardine and Simpson, 1990), 0.003 mg/kg in Collingwood Harbour (Beak, 1988a), 0.007 mg/kg in the St. Clair River (OMOE, unpublished 1985 data) and 0.006 mg/kg in Hamilton Harbour (Poulton, 1986). In contrast, levels markedly exceeding the above guideline have been found in the Detroit River (0.014 mg/kg) and near U.S. sources to the Niagara River (0.0612 mg/kg) (Jaagumagi and Persaud, 1992). Therefore, there would be concern over the toxicity of this compound to the more sensitive species of sediment-dwelling organisms and its possible biomagnification in the food chain (Persaud et al., 1991).

Concentrations of this compound in biota are usually low. For example, levels in net plankton collected from 33 southern Ontario lakes ranged from 0.0003 mg/kg to 0.0125 mg/kg (dry weight) (Taylor et al., 1990). In contrast, phytoplankton samples from the St. Clair River near industrial discharges contained from 2 to 18 mg/kg (OMOE and MDNR, 1991). Oligochaetes from sediments of Toronto's Humber Bay contained up to 0.031 mg/kg (wet weight) (EC, OMOE, OMNR and MTRCA, 1989). Emergent (adult) caddisflies and mayflies contained up to 0.014 mg/kg (dry weight) in the St. Clair River and 0.017 mg/kg in the Detroit River, compared to 0.001 mg/kg to 0.008 mg/kg in inland waters (Kovats and Ciborowski, 1989). The maximum concentration in adult sculpin from Collingwood Harbour was 0.004 mg/kg (wet weight) (OMOE and EC, 1989). (also see below re 'total BHCs' in young-of-the-year spottail shiners).

gamma-1,2,3,4,5,6-Hexachlorocyclohexane (Lindane)

Use of BHC was restricted in the 1970s (Cox and Ralston, 1990). However, lindane is still used on a limited basis for seed and soil treatment, foliar applications on fruit trees, vegetables and ornamentals, for wood protection (debarros, 1984) and as a scabicide (Verschueren, 1983).

This pesticide has been detected in water, sediment or biota samples from most Great Lakes Areas of Concern. Concentrations in some samples exceed available criteria for water and sediment (Tables 2.4 and 2.5).

Similarly to the alpha isomer, the gamma isomer is present throughout the Great Lakes Basin, but is usually found at lower concentrations in water. Lakewide mean concentrations in the Great Lakes range from 0.671 ng/l in Georgian Bay to 1.250 ng/l in Lake Ontario (IJC, 1989). At the outlet of Lake Ontario to the St. Lawrence River, mean concentrations during 1987 ranged from 0.56 ng/l to 0.75 ng/l (Tsanis et al., 1989). Higher concentrations have been detected in the nearshore close to urban-industrial complexes. Examples, with their maximum levels include 3 ng/l in Peninsula Harbour (Jardine and Simpson, 1990), 14 ng/l in the St. Clair River (Jaagumagi and Persaud, 1992), 4 ng/l in the Detroit River (Kauss and Hamdy, 1985), 45 ng/l in Canagagigue Creek (Jaagumagi et al., 1991a), in 59 ng/l in Hamilton Harbour (Poulton, 1986) and 89 ng/l at the mouth of the Don River in Toronto (Boyd, 1988). The St. Clair River, Hamilton and Toronto maxima exceed the PWQO and the GLWQA objective of 10 ng/l for the protection of aquatic life. Elevated levels have also been detected in effluents of municipal sewage treatment plants (up to 185 ng/l) and of some industries (up to 25 ng/l) in the Bay of Quinte area (Poulton, 1990).

In the Toronto area, a maximum of 0.015 mg/kg (dry weight) was associated with the suspended sediment fraction in the Don River, a Lake Ontario tributary at Toronto (Boyd, 1988).

Except near some point sources or hazardous waste sites, this organochlorine pesticide is not frequently detected in surficial sediment samples. However, since the OMOE minimum reporting limit is 0.001 mg/kg, it is difficult to determine what proportion of sediment samples exceed the proposed OMOE 'no effect level' sediment quality guideline of 0.0002 mg/kg. Those occasional samples with detectable levels can slightly exceed the proposed OMOE 'lowest effect level' guideline of 0.003 mg/kg. These include the maximum concentrations of 0.005 mg/kg (dry weight) in the St. Clair River (OMOE and MDNR, 1991), 0.004 mg/kg in Collingwood Harbour (Beak, 1988), 0.007 mg/kg in Canagagigue Creek (Jaagumagi et al., 1991a) and 0.008 mg/kg in Rice Lake (Jaagumagi and Persaud, 1992). These levels cause concern over lindane toxicity to the more sensitive species of sediment-dwelling organisms and its possible biomagnification up through the food chain (Persaud et al., 1991).

Concentrations of lindane in biota are generally low or non detectable. For example, levels in net plankton from different southern Ontario lakes ranged from 0.0006 mg/kg to 0.0145 mg/kg (dry weight) (Taylor et al., 1990). Oligochaetes from

sediments of Toronto Harbour contained a maximum of 0.015 mg/kg (wet weight) (EC, OMOE, OMNR and MTRCA, 1989). Emergent (adult) caddisflies and mayflies contained a maximum of 0.006 mg/kg (dry weight) in the St. Clair River and 0.013 mg/kg in the Detroit River, compared to 0.0005 mg/kg to 0.004 mg/kg in inland waters (Kovats and Ciborowski, 1989). Low concentrations are also exemplified by recent (1985-1988) data on 'total BHCs' (which includes the alpha, beta and gamma isomers of hexachlorocyclohexane) in young-of-the-year spottail shiners from various nearshore collection sites in the Great Lakes. Overall, BHCs were 'not detected' at all sites in Lake Superior, the St. Marys River, Lake Huron, the St. Clair River, Lake St. Clair, the Detroit River, Lake Erie and the St. Lawrence River, and in Lake Ontario fish only reached 0.002 mg/kg (wet weight). However, a mean concentration of 0.267 mg/kg (wet weight) was found in fish collected near a source on the U.S. side of the Niagara River (Suns et al., 1991). This exceeds the New York State criterion of 0.1 mg/kg for the protection of fish-eating birds (Newell et al., 1987).

Concentrations of lindane in the edible portion of Ontario sport fish are below the GLWQA specific objective of 0.3 mg/kg for the protection of human consumers.

Mercury

Mercury occurs naturally in bedrock and fossil fuels such as coal. This element has been used, either in its elemental form or as organic compounds in: chlorine production; the manufacture of batteries, switches, thermometers, barometers and mercury vapour lamps; gold and silver mining; slimicides; fungicides for paints, coatings and golf greens; and in dental filling amalgams. Due to restrictions in the late 1960s and early 1970s, losses to the aquatic environment from industrial point sources have decreased significantly (Cox and Ralston, 1990; deBarros, 1984).

The presence of mercury in the ecosystem has resulted in beneficial use impairments throughout the Great Lakes and in many inland waters due to exceedances of criteria for water, sediment or biota (Tables 2.4 and 2.5).

Mercury concentrations in open waters are very low. For example, the median dissolved and particulate-associated levels for the Great Lakes were 0.00 ug/l and 0.0010 ug/l in Lake Superior, 0.0042 ug/l in Lake Huron (no particulate data), 0.024 ug/l and 0.00020 ug/l in Lake Erie and 0.011 ug/l and 0.00020 ug/l in Lake Ontario (Rossman and Barres, 1988). Nevertheless, in occasional whole water samples from localized areas, levels of mercury have exceeded the PWQO and the GLWQA objective of 0.2 ug/l for the protection of aquatic life. These locations, with their maximum levels, include 0.36 ug/l in the Nipigon River (OMOE, EC, OMNR and F&OC, 1991a), 0.48 ug/l in the St. Marys River (Jaagumagi et al., 1991c), 0.21 ug/l in the St. Clair River (Jaagumagi and Persaud, 1992), 0.31 ug/l in Wheatly Harbour (OMOE, EC, OMNR and OMAF, 1990), 0.23 ug/l in Port Weller Harbour(Jaagumagi and Persaud, 1992), 0.26 ug/l in Hamilton Harbour (Poulton, 1986), 0.31 ug/l, 0.34 ug/l and 0.25 ug/l in Toronto's Humber Bay, Inner Harbour and East Headland areas (Jaagumagi and Persaud, 1992), 0.24 ug/l in the Bay of Quinte (Jaagumagi and Persaud, 1992). Concentrations of up to 0.449 ug/l were

found in the Trenton Channel on the Michigan side of the Detroit River (MDNR and OMOE, 1991).

Concentrations of mercury associated with the suspended sediment phase of water were as high as 0.34 mg/kg (dry weight) in Thunder Bay (Boyd, 1990), 0.40 mg/kg in the St. Clair River, 0.47 mg/kg in the Detroit River (Johnson and Kauss, 1987), 1.00 mg/kg in Talfourd Creek, a tributary of the St. Clair River (Johnson and Kauss, 1991), 10.00 mg/kg adjacent to a lakefilling area in Toronto's Outer Harbour (Boyd, 1988), and up 0.23 mg/kg in the St. Lawrence River near Cornwall (OMOE and EC, 1990). A net increase in the mean daily loading between the head and mouth of both the St. Clair River (6.61 kg/d) and the Detroit River (6.60 kg/d) was calculated based on the above data (Johnson and Kauss, 1987).

Surficial sediments contained up to 0.66 mg/kg (dry weight) in Thunder Bay (Boyd, 1990), 8.80 mg/kg in Peninsula Harbour (Jardine and Simpson, 1990), 0.23 mg/kg in Jackfish Bay (Beak, 1988b), 0.38 mg/kg in the St. Marys River (Hesselberg and Hamdy, 1987), 1.00 mg/kg in Midland Bay (OMOE, EC, OMNR and OMAF, 1988), 1.00 mg/kg in Collingwood Harbour (Jaagumagi, 1988), 1.00 mg/kg in Midland Harbour (Jaagumagi, 1988), 51.00 mg/kg in the St. Clair River (OMOE and MDNR, 1991), 0.62 mg/kg in the Detroit River (Thornley and Hamdy, 1984), 1.20 mg/kg in the Niagara River (Creese, 1987), 0.48 mg/kg in Hamilton Harbour (Jaagumagi and Persaud, 1992), 0.22 mg/kg in Oakville Harbour (Jaagumagi, 1988), 0.86 mg/kg, 2.60 mg/kg, 8.50 mg/kg and 0.33 mg/kg in Toronto's Humber Bay, Inner Harbour, Ashbridges Bay and East Headland, respectively (Jaagumagi, 1988, Jaagumagi et al., 1991d), 0.32 mg/kg in Rice Lake (Jaagumagi and Persaud, 1992), 0.73 mg/kg in the Bay of Quinte (Jaagumagi, 1988), and 0.47 mg/kg and 4.40 mg/kg, respectively, near Maitland and near Cornwall in the St. Lawrence River (Wilkins, 1988; OMOE and EC, 1990). Most of these values exceed both the present OMOE open water dredged material disposal guideline of 0.3 mg/kg as well as the proposed 'lowest effect level' sediment quality guideline of 0.2 mg/kg. Based on the latter guideline, there is concern regarding mercury toxicity to the more sensitive species of sediment-dwelling organisms and possible biomagnification through the food chain. Furthermore, the Peninsula Harbour, St. Clair River, Toronto (Inner Harbour and Ashbridges Bay) and Cornwall maxima exceed the proposed OMOE 'severe effect level' guideline of 2 mg/kg, a level above which pronounced disturbance of the sediment-dwelling community can be expected (Persaud et al., 1991).

Mercury concentrations in the filamentous alga Cladophora ranged up to 0.13 mg/kg (dry weight) in the Niagara River (OMOE, EC, OMNR and F&OC, 1991c), almost three times the maximum of 0.05 mg/kg reported for Wheatly Harbour (OMOE, EC, OMNR and OMAF, 1991). Oligochaetes from Toronto Harbour sediments contained up to 0.081 mg/kg (wet weight) of mercury (EC, OMOE, OMNR and MTRCA, 1989). Oligochaetes, chironomids and amphipods from Collingwood Harbour sediments contained up to 0.206 mg/kg, 0.101 mg/kg and 0.218 mg/kg, respectively (OMOE and EC, 1989). Burrowing mayfly larvae exposed to contaminated Hamilton Harbour sediments accumulated up to 0.22 mg/kg, in contrast to the control culture organisms, which contained a maximum of 0.09 mg/kg (Krantzberg,1991).

Mercury is detectable in most young-of-the-year spottail shiner collections from the Great Lakes; however, concentrations do not presently exceed the GLWQA objective of 0.5 mg/kg (wet weight) in whole fish for the protection of aquatic life and fish-eating birds. Furthermore, significant declines in mercury levels were recorded in the Big Creek, Leamington and the Grand River (in Lake Erie) and the Niagara-on-the-Lake (in the Niagara River) collection sites between the mid to the late 1970s. Levels have, however, remained virtually unchanged since then (Suns et al., 1985). The maximum mercury concentration in adult sculpin from Collingwood Harbour was 0.086 mg/kg (OMOE and EC, 1989).

Although mercury levels have also declined in sport fish at some locations in recent years (OMOE and OMNR, 1991), restricted human consumption advisories for larger sizes of various species are still widespread throughout the Great Lakes and Ontario's inland waters. These are related to mercury concentrations above the Health and Welfare Canada objective of 0.5 mg/kg. Such areas include Thunder Bay, Nipigon Bay, Jackfish Bay, Peninsula Harbour, St. Marys River, Spanish River, Georgian Bay, Lake Huron, St. Clair River, Lake St. Clair, Detroit River, Lake Erie, Niagara River, Lake Ontario, Bay of Quinte, the St. Lawrence River at Cornwall and the English-Wabigoon system (OMOE and OMNR, 1991).

Mercury is also present at elevated concentrations in the higher trophic levels of the Great Lakes ecosystem, such as waterfowl and piscivorous birds (Allan et al., 1991).

Pentachlorophenol

Pentachlorophenol is mainly used as a preservative in the lumber and leather tanning industry (deBarros, 1984).

Pentachlorophenol has been detected in some Ontario inland surface waters and Areas of Concern, and in certain cases, concentrations exceed available water criteria (Tables 2.4 and 2.5). There is presently no criterion for sediments.

Reported levels of pentachlorophenol in water range as high as 210,000 ng/l in the Kaministikwia River downstream of a paper mill discharge (Flood et al., 1989), 243 ng/l in nearby Thunder Bay (Boyd, 1990), 842 ng/l at the mouth of the Don River in Toronto (Boyd, 1988), and 710 ng/l in the Trent River, a major tributary of the Bay of Quinte (Poulton, 1990). Except for Thunder Bay, these values are above both the PWQO of 500 ng/l as well as GLWQA objective of 400 ng/l for the protection of aquatic life. During the period 1984-1988, levels of pentachlorophenol exceeded the PWQO in 4% of the samples and at six of the 25 river and stream monitoring sites; five of these were located downstream of pulp and paper mills or paper manufacturing industries (Whitehead, 1991).

Up to 0.0011 mg/kg (wet weight) of pentachlorophenol was associated with suspended sediment collected in the Rainy River downstream of a paper mill (Metcalfe and Hayton, 1989).

In a 1978 sediment core from the Bay of Quinte, pentachlorophenol concentrations reached their maximum of 0.061 mg/kg (dry weight) within the surficial (upper 3 cm) layers (Fox and Joshi, 1984). A maximum concentration of 0.550 mg/kg was recorded for the St. Lawrence River (Jaagumagi and Persaud, 1992).

Caged leeches exposed for three weeks in the Rainy River downstream of paper mill discharges, and in Thunder Bay Harbour near a wood preserving plant, accumulated up to 0.121 mg/kg and 5.300 mg/kg (wet weight) pentachlorophenol, respectively. Burrowing mayfly larvae, leeches and fathead minnows exposed to Thunder Bay Harbour sediments for ten days contained up to 0.068 mg/kg, 1.080 mg/kg and 0.061 mg/kg (wet weight), respectively (Metcalfe and Hayton, 1989). Oligochaetes from Canagagigue Creek (a tributary of the Grand River, which discharges to Lake Erie) contained up to 0.061 mg/kg (wet weight) (Jaagumagi et al., 1991a). Up to 0.172 mg/kg was accumulated by caged leeches exposed downstream of a phenolic resin plant on Frenchman's Creek, a Niagara River tributary (Anderson et al., 1991). Leeches exposed downstream of a wood-preserving plant in the Trent River (a major tributary of the Bay of Quinte) accumulated up to 19.0 mg/kg pentachlorophenol (Poulton, 1990).

Concentrations of up to 0.404 mg/kg (wet weight) by caged fathead minnows during a 96 hour exposure downstream of a paper mill discharge in Thunder Bay; concentrations in young-of-the-year walleye from the same study area were 0.113 mg/kg (Flood et al., 1989). Young-of-the-year yellow perch from downstream of a wood-preserving plant in the Trent River contained up to 1.963 mg/kg pentachlorophenol (Suns et al., 1991). This value is just below the New York State fish flesh criterion of 2 mg/kg (Newell et al., 1987) for the protection of fish-eating birds (Table 2.4).

Perylene

The environmental monitoring data base for this compound is relatively small compared to the other PAHs discussed here, since it is not always included in PAH analytical scans. Nevertheless, the data that are available indicate elevated concentrations in sediments and biota collected downstream of some Ontario sources. At some Great Lakes locations, sediment concentrations of perylene exceed the proposed OMOE sediment quality guideline for 'total PAHs'. There are presently no criteria for perylene in ambient water or aquatic biota. However, the GLWQA states that such contaminants should not be detectable in water or aquatic organisms (IJC, 1987).

Concentrations of perylene in surficial sediments ranged up to 11.0 mg/kg (dry weight) in the St. Marys River (Kauss and Hamdy, 1991). This value is above the proposed OMOE 'lowest effect level' sediment quality guideline of 2 mg/kg for 'total PAHs' and therefore there is concern over toxicity of this compound to the more sensitive species of sediment-dwelling organisms or possible biomagnification in the food chain (Persaud et al., 1991).

Maximum concentrations of perylene in caged freshwater mussels were 0.021 mg/kg (wet weight) after a three week exposure in the St. Marys River (Kauss and Hamdy, 1991), and 0.028 mg/kg and 0.041 mg/kg, respectively, after 18 weeks in the St. Clair and Detroit Rivers (OMOE, unpublished 1984 data).

Phenanthrene

Monitoring data indicate elevated concentrations of phenanthrene in samples collected near or downstream of some Ontario point source discharges, and at some locations, sediment concentrations exceed the proposed OMOE criterion for 'total PAHs'. There are presently no criteria for safe concentrations of phenanthrene in ambient water or aquatic biota. Nevertheless, the GLWQA states that such contaminants should not be detectable in water or aquatic organisms (IJC, 1987).

In the St. Marys River, whole water samples contained up to 587 ng/l (UGLCCS, 1988). Turkey Creek contained 170 to 180 ng/l and about 30 ng/l was found in Detroit River water downstream of this tributary (Cowell, 1990).

High concentrations of phenanthrene have been detected on fine particulate matter separated from water. For example, up to 8.379 mg/kg (dry weight) were associated with the suspended sediment phase in the St. Marys River (UGLCCS, 1988).

Concentrations of this PAH in surficial sediments ranged up to 1.12 mg/kg (dry weight) in Thunder Bay Harbour (EC, 1988), 22.40 mg/kg in the St. Marys River (Kauss, 1991), 8.51 mg/kg in the St. Clair River (OMOE, unpublished 1990 data), 5.58 mg/kg in the Grand River (Jaagumagi et al., 1991b), 189.0 mg/kg in Hamilton Harbour (Murphy et al., 1990), 20.00 mg/kg in Toronto's Ashbridges Bay (Jaagumagi et al., 1991d), 8.79 mg/kg in Rice Lake (Jaagumagi and Persaud, 1992), 16.00 mg/kg in the Bay of Quinte (Poulton, 1990) and 12.99 mg/kg in the St. Lawrence River (Jaagumagi and Persaud, 1992). With the exception of Thunder Bay, these maxima exceed the proposed OMOE 'lowest effect level' sediment quality guideline of 2 mg/kg for 'total PAHs' and therefore, there is concern over the toxicity of phenanthrene to the more sensitive species of sediment-dwelling organisms, as well as its possible biomagnification in the food chain (Persaud et al., 1991).

Elevated levels of phenanthrene have been detected in freshwater mussels: maximum concentrations were 0.969 mg/kg (wet weight) in caged mussels exposed along the Ontario side of the St. Marys River (Kauss and Hamdy, 1991), 0.096 mg/kg in the St. Clair River and 0.025 mg/kg in the Detroit River (OMOE, unpublished 1984 data). In the Niagara River, mussels exposed in Chippawa Creek contained 0.071 mg/kg phenanthrene (Anderson et al., 1991).

Fathead minnows exposed to sediment from Muddy Creek, a tributary of Wheatly Harbour, accumulated 1.001 mg/kg (wet weight) (OMOE, EC, OMNR and OMAF, 1991). Burrowing mayfly larvae and fathead minnows exposed to contaminated Hamilton Harbour sediments accumulated up to 3.115 mg/kg and 1.412 mg/kg (wet weight), respectively (Krantzberg, 1991).

Phenanthrene has also been detected in young-of-the-year spottail shiners from a number of Great Lakes monitoring sites. These include 0.039 mg/kg (wet weight) at the Kaministikwia River and 0.048 mg/kg at Goulais Bay, both in Lake Superior, 0.034 mg/kg at Collingwood Harbour, 0.086 mg/kg at Mitchell Bay in Lake St. Clair, 0.086 mg/kg at Amherstburg in the Detroit River, and 0.039 mg/kg and 0.124 mg/kg at the mouths of the Humber River and Trent River, respectively, both in Lake Ontario (Suns et al., 1991).

Phenanthrene has been found in some dorsal fillet samples from adult sport fish caught in Ontario waters. For example, in the St. Marys River, the maximum concentrations in walleye, chinook salmon and pink salmon were 0.063 mg/kg, 0.084 mg/kg and 0.027 mg/kg, respectively. In the lower Niagara River, the highest concentrations found in walleye, rainbow trout, lake trout and American eel were 0.017 mg/kg, 0.045 mg/kg, 0.014 mg/kg and 0.037 mg/kg, respectively (OMOE, unpublished 1989 data).

Polychlorinated Biphenyls (PCBs)

PCBs were manufactured in the United States between 1929 and 1977 and used in North America as: cooling and insulating fluids in transformers and capacitors; hydraulic fluids; surface coatings for carbonless copy paper; plasticizer in sealants, caulkings, synthetic resins rubbers, paints, waxes and asphalts; as a flame retardant in lubricating oils; pesticide extenders; and in printing inks and adhesives. As of 1977 in Canada, PCBs are only allowed in existing close-system electrical and hydraulic systems and are to be replaced at the end of their service life (Cox and Ralston, 1990; debarros, 1984).

PCBs have been detected in water, sediment and biota samples from most Great Lakes Areas of Concern. Their presence in the aquatic ecosystem at levels above criteria has resulted in
beneficial use impairments throughout the Great Lakes for these media (Tables 2.4 and 2.5).

Lakewide mean water concentrations of total PCBs increase gradually as one progresses down through the Great Lakes: 0.325 ng/l in Lake Superior, 0.573 ng/l in Lake Huron, 0.676 ng/l in Georgian Bay, 1.159 ng/l in Lake Erie, and 1.201 ng/l in Lake Ontario (IJC, 1989). At the outlet of Lake Ontario to the St. Lawrence River, mean concentrations during 1987 ranged from 1.32 ng/l to 1.34 ng/l (Tsanis et al., 1989). The above Lake Erie and Lake Ontario values, as well as the mean 'recombined whole water' concentrations at Fort Erie (3.90 ng/l) and at Niagara-on-the-Lake (1.66 ng/l) in the Niagara River (Niagara River Data Interpretation Group, 1988) and the average PCB concentrations in water at the head (1.4 ng/l) and mouth (3.3 ng/l) of the Detroit River (MDNR and OMOE, 1991) exceed the PWQO of 1 ng/l for the protection of aquatic life. Concentrations in some samples from Great Lakes nearshore areas have also exceeded the PWQO (Table 2.5). These locations, with their maximum levels, include 80 ng/l in Thunder Bay (Boyd, 1990), 1.14 ng/l in the Rainy River (Merriman, 1988), 950 ng/l in Nipigon Bay

(OMOE, EC, OMNR and F&OC, 1991a), 30 ng/l in Hamilton Harbour (Poulton, 1986) and 230 ng/l in Toronto Harbour (Jaagumagi and Persaud, 1992)

PCBs tend to be associated with fine sediment particles in water. For example, concentrations detected in the suspended sediment phase were up to 0.060 mg/kg (dry weight) in Thunder Bay (Boyd, 1990), 0.240 mg/kg in the Rainy River (Merriman, 1988), 0.041 mg/kg in the St. Clair River and 0.032 mg/kg in the Detroit River (Johnson and Kauss, 1987), and 0.400 mg/kg in material collected from the Don River in Toronto (Boyd, 1988). A net increase in the daily loading between the head and mouth of the St. Clair River (0.3 kg/d) and a net decrease in the Detroit River (-2.1 kg/d) was calculated based on the above 1984 monitoring data. In the Niagara River, there was a significant increase of 0.411 kg/d in the suspended sediment-associated daily loading between Fort Erie and Niagara-on-the-Lake (Niagara River Data Interpretation Group, 1988).

Surficial sediments contain up to 0.185 mg/kg (wet weight) of total PCBs in Thunder Bay (Boyd, 1990), 0.495 mg/kg in Peninsula Harbour (Jardine and Simpson, 1990), 0.490 mg/kg in the St. Marys River (Jaagumagi et al., 1991c)), 0.120 mg/kg in Penetang Harbour (OMOE, EC, OMNR and OMAF, 1988), 0.355 mg/kg in Collingwood Harbour (Jaagumagi and Persaud, 1992), 2.580 mg/kg in the St. Clair River (OMOE and MDNR, 1991), 0.370 mg/kg in the Detroit River (Thornley and Hamdy, 1984), 0.630 mg/kg in Muddy Creek which discharges to Wheatly Harbour (OMOE, EC, OMNR and OMAF, 1991), 0.965 mg/kg in the Grand River (Jaagumagi et al., 1991b), 0.705 mg/kg in the Niagara River (Creese, 1987), 0.255 mg/kg in Port Weller Harbour (Jaagumagi and Persaud, 1992), 3.090 mg/kg in Hamilton Harbour (Jaagumagi and Persaud, 1992), 0.310 mg/kg, 1.590 mg/kg, 0.990 mg/kg, 0.465 mg/kg and 0.300 mg/kg in Toronto's Humber Bay, Inner Harbour, Ashbridges Bay, East Headland and Bluffer's Park, respectively (Jaagumagi and Persaud, 1992), 0.077 mg/kg in Port Hope Harbour (EC and OMOE, 1990), 6.140 mg/kg in Rice Lake (Jaagumagi and Persaud, 1992), 0.880 mg/kg in the Trent River, a tributary of the Bay of Quinte (Poulton, 1990), 0.320 in the Bay of Quinte (Jaagumagi and Persaud, 1992) and 0.160 mg/kg and 1.010 mg/kg, respectively, near Maitland and Cornwall in the St. Lawrence River (Wilkins, 1988; OMOE and EC, 1990). These values exceed both the present OMOE open water dredged material disposal guideline of 0.050 mg/kg as well as the proposed 'lowest effect level' sediment quality guideline of 0.070 mg/kg. With respect to the latter guideline, these exceedances result in concerns over the toxicity of PCBs to the more sensitive species of sediment-dwelling organisms and possible biomagnification up through the food chain (Persaud et al., 1991).

Phytoplankton collected near Sarnia organic chemical industry discharges to the St. Clair River contained up to 3000 mg/kg (dry weight) of PCBs (OMOE and MDNR, 1991). PCB concentrations in the filamentous alga Cladophora ranged up to 0.032 mg/kg (dry weight) along the Ontario shore of the Niagara River (Anderson et al., 1991) 1991). Midge larvae exposed to Midland Bay sediments accumulated 0.060 mg/kg (wet weight) of PCBs (OMOE, EC, OMNR and OMAF, 1988). Oligochaetes from sediments of Toronto's Humber Bay contained up to 0.60 mg/kg of PCBs (EC, OMOE, OMNR and MTRCA, 1989). Maximum concentrations accumulated by caged freshwater mussels exposed in Ontario waters were

0.148 mg/kg (wet weight) in the Rainy River (Hayton and Hollinger, 1989), 0.096 mg/kg along the Ontario shore of St. Clair River (OMOE and MDNR, 1991), 0.293 mg/kg in the Detroit River (MDNR and OMOE, 1991) and 0.039 mg/kg in Chippawa Creek, a tributary of the Niagara River (Anderson et al., 1991). Relative to the control, fathead minnows accumulated up to 0.63 mg/kg (wet weight) PCBs during exposure to Wheatly Harbour sediments (OMOE, EC, OMNR and OMAF, 1991).

PCB concentrations in recent (1986-1988) collections of young-of-the-year spottail shiners from the Great Lakes are significantly lower than in the 1970's. Nevertheless, concentrations in fish from 34 % of the 73 recent Great Lakes collection sites in Ontario waters exceeded the GLWQA specific objective of 0.1 mg/kg for the protection of birds and animals which consume fish (Suns et al., 1991), indicating a potential for reproductive toxicity in higher trophic levels. These locations included: Midland and Collingwood in Lake Huron; Lambton in the St. Clair River; Turkey Creek and Amherstburg in the Detroit River; Big Creek, Leamington and Port Dover in Lake Erie; the Welland River, Queenston and Niagara-on-the-Lake in the Niagara River; the Welland Canal, Twelve Mile Creek, Burlington Beach, Bronte Creek, Oakville Creek, Credit River, Mimico Creek, Humber River, Toronto Harbour, Leslie Spit and Napanee River in Lake Ontario; and Cornwall in the St. Lawrence River. In addition to increases in the number of collections which exceed the GLWQA specific objective, maximum levels of PCBs in these juvenile fish also increase somewhat as one progresses down through the Great Lakes. For example, the highest concentration in any of the recent Ontario collection sites was 0.067 mg/kg (wet weight) in Lake Superior, 'not detected' in the St. Marys River, 0.206 mg/kg in Lake Huron, 0.283 mg/kg in the St. Clair River, 0.040 mg/kg in Lake St. Clair, 0.214 mg/kg in the Detroit River, 0.385 mg/kg in Lake Erie, 0.256 mg/kg in the Niagara River, 0.321 mg/kg in Lake Ontario and 0.182 mg/kg in the St. Lawrence River (Suns et al., 1991). The maximum concentration of PCBs in adult sculpin from Collingwood Harbour was 0.11 mg/kg (OMOE and EC, 1989).

Although levels of PCBs in sport fish have also declined at some Ontario locations in recent years, restricted human consumption advisories for larger sizes of certain species are still widespread throughout the Great Lakes and some Ontario inland waters. These are related to concentrations above the Health and Welfare Canada guideline of 2.0 mg/kg. Such areas include Thunder Bay, Nipigon Bay, Jackfish Bay, Peninsula Harbour, Spanish River, Georgian Bay, Lake Huron, St. Clair River, Lake St. Clair, Detroit River, Lake Erie, Niagara River, Lake Ontario including Toronto and the Bay of Quinte, and the St. Lawrence River at Cornwall (OMOE and OMNR, 1991).

PCBs are also present at elevated concentrations in the higher levels of the Great Lakes food chain, such as waterfowl, piscivorous birds and snapping turtles (Allan et al., 1991).

Polychlorinated Dibenzo-p-Dioxins and Furans

Polychlorinated dibenzo-p-dioxins (PCDDs) and polychlorinated dibenzofurans (PCDFs) are byproducts created during the manufacture of certain organochlorine pesticides (e.g., 2,4-D, 2,4,5-T, 2,4,5-trichlorophenol, pentachlorophenol, hexachlorophenol) or as a result of incomplete combustion (or reactions between) mixtures containing both chlorine and organic compounds (Cox and Ralston, 1990). One of the PCDDs, 2,3,7,8-TCDD, is an impurity in the herbicide 2,4,5-T (deBarros, 1984).

Elevated (above background or control) levels of these compounds have been found in water, sediment and biota samples from areas receiving industrial inputs, such as pulp and paper mills using chlorine bleaching. Their presence in the ecosystem at levels exceeding available criteria for fish has resulted in beneficial use impairments in certain locations in the Great Lakes Basin (Tables 2.4 and 2.5). At present, there are no sediment criteria for individual or total PCDDs and PCDFs.

PCDDs or PCDFs have been detected at low concentrations (below objective) in a few of the raw water samples collected at Ontario drinking water intakes in the St. Clair River (OMOE and MDNR, 1991) and the Detroit River (MDNR and OMOE, 1991).

Concentrations of up to 0.0115 ug/kg 2,3,7,8-TCDD (wet weight) and up to 0.149 ug/kg Octa-CDD were associated with the suspended sediment phase in the Rainy River downstream of discharges from pulp and paper mills (Merriman, 1988).

A survey of surficial sediments near Canadian pulp and paper mills using chlorine bleaching found that the presence of different PCDD and PCDF congeners and their abundance differed greatly in samples collected downstream of the discharges (Trudel, 1991). Due to the different toxicities of these compounds, this makes a comparison of the sites on the basis of toxicological significance difficult. Concentrations of the various congeners and isomers were therefore converted to toxic equivalent (TEQ) values using toxic equivalency factors in relation to 2,3,7,8-TCDD, the most toxic compound (NATO, 1988). For the ten locations in Ontario with such mills, the maximum 2,3,7,8-TCDD TEF concentrations in downstream sediments were: 0.017 ug/kg (dry weight) in the Rainy River, 0.208 ug/kg in Clay Lake, 0.019 ug/kg in the Kaministikwia River at Thunder Bay, 0.036 ug/kg in Nipigon Bay, 0.163 ug/kg in Jackfish Bay, 0.066 ug/kg at Peninsula Harbour, 0.019 ug/kg at Smooth Rock Falls, 0.023 ug/kg in the Spanish River, 0.046 ug/kg in the Old Welland Canal, and 0.108 ug/kg at Cornwall in the St. Lawrence River (Trudel, 1991). It should, however be noted that only at Clay Lake, Nipigon Bay, Jackfish Bay, Peninsula Harbour, and Cornwall were these concentrations higher than at the upstream or control locations.

Sediment downstream of a phenolic resin plant in Frenchman's Creek, an Ontario tributary to the Niagara River, contained up to 0.210 ug/kg Hepta-CDD, 0.900 ug/kg Octa-CDD, 0.060 ug/kg Hexa-CDF, 0.440 ug/kg Hepta-CDF, and 0.440 ug/kg Octa-CDF (Anderson et al., 1991). Much higher concentrations of PCDDs and PCDFs were found in Thunder Bay Harbour sediments adjacent to a wood preserving plant; i.e, up to 0.32 ug/kg Tetra-CDD, 1.90 ug/kg Penta-CDD, 7.30 ug/kg Hexa-CDD,

480 ug/kg Hepta-CDD, 1700 ug/kg Octa-CDD, 0.070 ug/kg Tetra-CDF, 0.320 ug/kg Penta-CDF, 7.700 ug/kg Hepta-CDF, 51 ug/kg Hepta-CDf and 99 ug/kg Octa-CDF (EC, 1988). For comparison, levels in sediments of the Pettit Flume on the U.S. side of the Niagara River were 9 ug/kg 2,3,7,8-TCDD, 620 ug/kg Tetra-CDD, 560 ug/kg Penta-CDD, 980 ug/kg Hexa-CDD, ~360 ug/kg Hepta-CDD, ~400 ug/kg Octa-CDD, 1700 ug/kg Tetra-CDF, 2700 ug/kg Penta-CDF, 7400 ug/kg Hexa-CDF, ~3900 ug/kg Hepta-CDF and ~13000 ug/kg Octa-CDF (Anderson et al., 1991)

Shrimp (Mysis relicta) from Jackfish Bay contained 9 ng/kg (wet weight) of 2,3,7,8-TCDD, 48 ng/kg Tetra-CDF, 16 ng/kg penta-CDF and trace levels of Penta-CDD, Hexa-CDD, Hexa-CDF and Hepta-CDF. After three weeks of exposure in Jackfish Bay, caged mussels accumulated 34 ng/kg Tetra-CDF and trace levels of Tetra-CDD (Sherman et al., 1990). The maximum concentration of 2,3,7,8-TCDD accumulated over three weeks by caged freshwater mussels exposed in Ontario waters of the Rainy River was 5.4 ng/kg (wet weight). These mussels also contained up to 20 ng/kg Hepta-CDD and 8.2 ng/kg Octa-CDD (Hayton and Hollinger, 1989). In the Niagara River, caged mussels from Ontario sites contained up to 5 ng/kg Hepta-CDD, 7 ng/kg Octa-CDD and 63 ng/kg Tetra-CDF after three weeks. In contrast, mussels exposed along the U.S. shore of the upper river at the Pettit Flume accumulated 200 ng/kg 2,3,7,8-TCDD, 3400 ng/kg Tetra-CDD, 3300 ng/kg Penta-CDD, 200 ng/kg Hexa-CDD, 70 ng/kg Octa-CDD, 20000 ng/kg Tetra-CDF, 55000 ng/kg Penta-CDF, 10000 ng/kg Hexa-CDF, 3800 ng/kg Hepta-CDF and 3300 ng/kg Octa-CDF (Anderson et al., 1991). In the St. Lawrence River at Cornwall, caged mussels accumulated up to 5 ng/kg Tetra-CDF and 3 ng/kg Penta-CDF (OMOE and EC, 1990).

Young-of-the-year spottail shiners collected from the Ontario nearshore of the St. Clair River in 1985 contained 274 ng/kg (wet weight) Penta-CDF (OMOE and MDNR, 1991). In 1981, the average concentration of 2,3,7,8-TCDD in spottail shiners from Niagara-on-the-Lake in the lower Niagara River (14 ng/kg, wet weight) exceeded the New York State fish flesh criterion of 3 ng/kg for 'total TCDDs' established by Newell et al. (1987) to protect fish-eating birds and mammals. Concentrations at this location decreased to 'not detected' in 1982 and 1983 collections (Suns et al., 1983).

There are presently restrictions on the consumption of some sport fish species from Lake Superior, the Niagara River, and Lake Ontario due to concentrations above the Health and Welfare Canada guideline for human consumption of 0.00002 mg/kg (= 20 ng/kg) 2,3,7,8-TCDD (OMOE and OMNR, 1991; Allan et al., 1991). Elevated levels of PCDDs and PCDFs have also been detected in the eggs of herring gulls and snapping turtles from areas receiving industrial inputs (Allan et al., 1991).

Tributyltin

Of the organotin compounds used in Canada, diorganotins are mainly used as plastic stabilizers or feed additives, triorganotins as biocides, and tetraorganotins as industrial catalysts (Wong and Chau, 1990). The most significant environmental usage of tributyltin is as the active ingredient in antifoulant paints (either as the

fluoride or oxide) that are applied to boat hulls to prevent growth of attached algae and bacteria (Jones and Millson, 1982; Wong and Chau, 1990). Tributyltin oxide is also used as a slimicide in cooling water towers and as a wood preservative (Jones and Millson, 1982).

There are presently no criteria for safe concentrations of tributyltin (TBT) in receiving waters, sediment or aquatic biota. More importantly, the present lack of routine OMOE analytical methods for these matrices or for effluents precludes the ability to determine loadings to the environment. Environment Canada has however, been testing for organotins in the Great Lakes in recent years.

Although not detected in subsurface water samples from the St. Clair River, TBT was found in surface microlayer samples from two of the stations sampled, with a maximum concentration of 33 ng/L (as tin) (Maguire et al., 1985). In the Detroit River, TBT was found in subsurface water samples from eight of 23 stations sampled, with a maximum concentration of 38 ng/L in Ontario waters and 70 ng/L in Michigan waters.

Sewage treatment plant effluent and sludge samples were collected from three cities (Sarnia, Toronto, and Hamilton) and analyzed for butyltin compounds (Chau et al., 1992). Monobutyltin was found in all effluent samples. Monobutyl-, dibutyl-, and tributyltin were found in sludge samples collected from Toronto and Sarnia.

The maximum concentration of TBT found in the St. Clair River sediments was 0.007 mg/kg, whereas in the Detroit River it ranged as high as 0.008 mg/kg in Ontario and 0.072 mg/kg in Michigan (Maguire et al., 1985). TBT concentrations of up to 0.045 mg/kg and 0.055 mg/kg were found in Oshawa and Whitby Harbours, respectively (Chau et al., 1989).

In a survey of Severn Sound, an Area of Concern with numerous marinas, tributyltin was found in sediments from as many as 14 of the 18 stations sampled. Concentrations varied seasonally, with maxima of 0.444 mg/kg (dry weight) being detected in the spring, 0.392 mg/kg in the summer, and 0.163 mg/kg in the fall (Wong and Chau, 1990). Dibutyltin and monobutyltin, degradation products of tributyl tin, were also detected in some sediment samples, but not in biota.

In the same study, five of 11 caged mussels from different stations contained tributyltin concentrations of 0.059 mg/kg to 0.066 mg/kg (wet weight). Young-of-the-year fish from two areas in Severn Sound contained from 0.009 mg/kg to 0.040 mg/kg. Northern pike contained up 0.240 mg/kg in the spring but no tributyltin in the fall. This seasonal variation was thought to be related to the release of tributyltin from the sediments (see above) and the leaching of this compound from freshly-painted boats placed in the water (Wong and Chau, 1990).

Chau et al. (1989) reported accumulations of up to 0.091 mg/kg and 0.682 mg/kg in caged mussels exposed in Oshawa and Whitby Harbours, respectively.

DDT and Metabolites

The use of DDT was banned in Ontario in 1969, except for the control of rodents and bats in enclosed areas by special permit. In the United States, its use was banned in 1972. However, the pesticide dicofol (Kelthane) has been found to be contaminated with from 2.5% to about 6% of DDT residues. The latter include the o,p and p,p' isomers of DDT, as well as DDD, DDE and extra chlorine DDT (Kauss and Post, 1987).
Lakewide mean water concentrations of p,p'-DDE increase from Lake Superior to Lake Ontario: 'not detected' in Lake Superior, 0.012 ng/l in Lake Huron, 0.020 ng/l in Georgian Bay, 0.032 ng/l in Lake Erie, and 0.050 ng/l in Lake Ontario (IJC, 1989). These average levels are well below the PWQO for DDT plus metabolites of 3 ng/l for the protection of aquatic life. Nevertheless, the maximum concentrations in some Areas of Concern or in the Great Lakes watershed exceeded the PWQO (Table 2.5). These include 19 ng/l p,p'-DDE in Thunder Bay (Boyd, 1990), 4 ng/l p,p'-DDE at the mouth of Pike Creek, a tributary of Lake St. Clair (Johnson and Kauss, 1991), 17 ng/l p,p'-DDT in Canagagigue Creek, a tributary of the Grand River which discharges to Lake Erie (Jaagumagi et al., 1991a) and 5 ng/l of p,p'-DDT at a lakefilling area in the Toronto waterfront (Boyd, 1988).

In tributaries discharging to the St. Clair River, Lake St. Clair and the Detroit River, virtually all of the loadings of DDT and its metabolites were associated with the suspended sediment phase. The maximum concentrations on a dry weight basis of o,p-DDT (0.015 mg/kg), p,p'-DDT (0.045 mg/kg), p,p'-DDD (0.050 mg/kg) and of p,p'-DDE (0.033 mg/kg) were found in Turkey Creek, a Detroit River tributary (Johnson and Kauss, 1991). In the Toronto area, the maximum concentrations of 0.010 mg/kg o,p-DDT and 0.060 mg/kg p,p'-DDT were associated with a lakefilling area on the waterfront, whereas the maximum of 0.025 mg/kg p,p'-DDD was found at the mouths of Mimico Creek, the Don River and the Humber River, all Lake Ontario tributaries. A maximum of 0.088 mg/kg p,p'-DDE was recorded in the Don River (Boyd, 1988).

Surficial sediments contain up to: 0.002 mg/kg (dry weight) each of o,p-DDT and p,p'-DDD and 0.004 mg/kg of p,p'-DDE in Thunder Bay (Boyd, 1991); 0.005 mg/kg p,p'-DDE in Peninsula Harbour (Jardine and Simpson, 1990); 0.037 mg/kg p,p'-DDD and 0.088 mg/kg p,p'-DDE in the St. Marys River (Jaagumagi et al., 1991c); 0.010 mg/kg p,p'-DDT, 0.015 mg/kg p,p'-DDD and 0.036 mg/kg p,p'-DDE in Collingwood Harbour (Jaagumagi and Persaud, 1992); 0.008 mg/kg p,p'-DDE in Midland Bay (Jaagumagi and Persaud, 1992); 0.010 mg/kg p,p'-DDE in Penetang Harbour (Jaagumagi and Persaud, 1992); 0.025 mg/kg p,p'-DDT, 0.050 mg/kg p,p'-DDT and 0.049 mg/kg p,p'-DDE in the St. Clair River (OMOE and MDNR, 1991); 0.049 mg/kg total DDT in the Detroit River (Thornley and Hamdy, 1984); 0.015 mg/kg p,p'-DDD and 0.047 mg/kg p,p'-DDE mg/kg in Wheatly Harbour (OMOE, EC, OMNR and OMAF, 1991); 0.030 mg/kg o,p-DDT, 6.030 mg/kg p,p'-DDT, 0.150 mg/kg p,p'-DDD and 0.050 mg/kg p,p'-DDE in Canagagigue Creek (Jaagumagi et al., 1991a); 0.030 mg/kg p,p'-DDT in the Grand River (Jaagumagi et al., 1991b); 0.017 mg/kg p,p'-DDE in the Niagara River (Creese, 1987); 0.022 mg/kg p,p'-DDE in Port Weller Harbour (Jaagumagi and Persaud, 1992); 0.005 mg/kg o,p-DDT, 0.077 mg/kg p,p'-DDT, 0.050 mg/kg p,p'-DDD and 0.096 mg/kg p,p'-DDE in Hamilton Harbour

(OMOE, OMNR, OMAF, EC, FOC and RBG, 1989; Jaagumagi and Persaud, 1992); 0.030 mg/kg p,p'-DDT, 0.215 mg/kg p,p'-DDD and 0.034 mg/kg p,p'-DDE in Toronto's Inner Harbour (Jaagumagi and Persaud, 1992); 0.010 mg/kg p,p'-DDD and 0.024 mg/kg p,p'-DDE in Rice Lake (Jaagumagi and Persaud, 1992); 0.100 mg/kg p,p'-DDT and 0.034 mg/kg p,p'-DDE in the Bay of Quinte (Poulton, 1990; Jaagumagi and Persaud, 1992); and 0.015 mg/kg and 0.006 mg/kg, respectively, of p,p'-DDE near Maitland and Cornwall in the St. Lawrence River (Wilkins, 1988; OMOE and EC, 1990). These values exceed the proposed 'lowest effect level' sediment quality guidelines of 0.007 mg/kg for total DDT, 0.008 mg/kg for o,p + p,p'-DDT, 0.008 mg/kg for p,p'-DDD and 0.005 mg/kg for p,p'-DDE. Consequently, these exceedances lead to concerns over the toxicity of DDT compounds to the more sensitive species of sediment-dwelling organisms and possible biomagnification up through the food chain. In addition, the concentration of p,p'-DDT in Canagagigue Creek exceeded the proposed OMOE 'severe effect level' sediment quality guideline of 71 mg/kg (based on total organic carbon content), a level above which pronounced disturbance of the sediment-dwelling community can be expected (Persaud et al., 1991).

Phytoplankton collected near Sarnia industrial discharges to the St. Clair River contained up to 13 mg/kg, dry weight of DDT, 27 mg/kg p,p'-DDD and 75 mg/kg p,p'-DDE (OMOE and MDNR, 1991). Net plankton from a variety of southern Ontario lakes contained from 0.005 mg/kg to 0.084 mg/kg DDT, 0.0007 mg/kg to 0.184 mg/kg DDD and 0.003 mg/kg to 0.096 mg/kg DDE (Taylor et al., 1990).

The maximum wet weight concentrations of DDT or its metabolites in samples of benthic macroinvertebrates from the following areas were: 0.003 mg/kg p,p'-DDD and 0.002 mg/kg p,p'-DDE in oligochaetes from the St. Marys River (Jaagumagi et al., 1991c); 0.013 mg/kg p,p'-DDD in chironomids and 0.010 mg/kg p,p'-DDE in dragonfly larvae from Canagagigue Creek (Jaagumagi et al., 1991a); and 0.032 mg/kg p,p'-DDD and 0.051 mg/kg p,p'-DDE in oligochaetes from Toronto Harbour and from Humber Bay, respectively (EC, OMOE, OMNR and MTRCA, 1989). Emergent (adult) caddisflies or mayflies contained up to 0.027 mg/kg (dry weight) of p,p'-DDT in the Detroit River, and 0.001 mg/kg to 0.012 mg/kg in inland waters. In the same insects, mean levels of p,p'-DDE ranged as high as 0.036 mg/kg in the St. Clair River, 0.063 mg/kg in the Detroit River, and 0.022 mg/kg to 0.046 mg/kg in inland waters (Kovats and Ciborowski, 1989). Caged mussels exposed in the St. Clair and Detroit Rivers accumulated maximum mean concentrations of 0.004 mg/kg p,p'-DDE (Kauss and Hamdy, 1985).

Levels of DDT compounds ranged up: to 0.014 mg/kg o,p + p,p'-DDT, 0.004 mg/kg p,p'-DDD and 0.017 mg/kg p,p'-DDE in sculpin from the St. Marys River (Jaagumagi et al., 1991c); 0.219 mg/kg p,p'-DDE in minnows from Canagagigue Creek (Jaagumagi et al., 1991a); 0.005 mg/kg p,p'-DDD and 0.035 mg/kg p,p'-DDE in minnows from the Grand River (Jaagumagi et al., 1991b); and 0.012 mg/kg p,p'-DDD and 0.127 mg/kg p,p'-DDE in sculpin from Toronto (Jaagumagi et al., 1991d).

Total DDT concentrations in young-of-the-year spottail shiners from the Great Lakes and the St. Lawrence River declined significantly between the mid-1970's and the

most recent (1986-1988) samples. Levels in all recent samples from Ontario Great Lakes waters are well below the GLWQA specific objective of 1.0 mg/kg (wet weight) for the protection of birds and animals which consume fish and also below the New York State criterion of 0.200 mg/kg (Newell et al., 1987). For example, the highest mean concentration in these fish during the period 1986-1988 was 0.091 mg/kg at the mouth of the Credit River in Lake Ontario (Suns et al., 1991).

Although DDT and its metabolites (mainly the metabolites) are still being detected in the edible portions of Ontario sport fish, principally in those from Lake Ontario, concentrations have decreased significantly since the late 1960s. In 1967, Lake Simcoe lake trout contained an average of 15.7 mg/kg 'total DDT' (DDT + metabolites). Since 1977, no sport fish samples have exceeded the Health and Welfare Canada guideline of 5.0 mg/kg for the protection of human consumers (Cox and Ralston, 1990). Currently, mean concentrations of 'total DDT' in lake trout from six major Ontario waterbodies are: 0.030 mg/kg (wet weight) in Lake Superior, 0.079 mg/kg in Lake Nipigon, 0.202 mg/kg in Lake Huron, 0.229 mg/kg in Lake Simcoe, 0.065 mg/kg in Lake Erie, and 1.230 mg/kg in Lake Ontario (Cox, pers. comm. Feb. 1991).

Dieldrin

Aldrin and its toxic metabolite dieldrin were banned from use in Ontario in 1969 and in the United States in 1974. Although aldrin is rapidly converted to dieldrin by aquatic organisms, the latter is very persistent (Cox and Ralston, 1990). Dieldrin is still detectable in the aquatic environment, and in some areas its levels exceed criteria for water and sediment (Tables 2.4 and 2.5).

Lakewide mean water concentrations of dieldrin increase slightly from the upper to the lower Great Lakes: 0.287 ng/l in Lake Superior, 0.361 ng/l in Lake Huron, 0.321 ng/l in Georgian Bay, 0.367 ng/l in Lake Erie, and 0.310 ng/l in Lake Ontario (IJC, 1989). At the outlet of Lake Ontario to the St. Lawrence River, mean concentrations during 1987 ranged from 0.23 ng/l to 0.25 ng/l (Tsanis et al., 1989). Concentrations in some samples from Great Lakes nearshore areas have exceeded the PWQO of 1 ng/l for the protection of aquatic life (Table 2.5). These locations, with their maximum levels, include 3 ng/l in Port Weller Harbour (Jaagumagi and Persaud, 1992), 8 ng/l at the mouth of the Don River (Boyd, 1988) and 37 ng/l in Ashbridges Bay (Jaagumagi and Persaud, 1992), both in the Toronto area.

Dieldrin readily partitions onto particulate matter in water. For example, all of the loadings of dieldrin from tributaries discharging to the St. Clair River, Lake St. Clair and the Detroit River were associated with the suspended sediment phase. The maximum concentration of 0.088 mg/kg (dry weight) was recorded at the mouth of Talfourd Creek, a St. Clair River tributary (Johnson and Kauss, 1991). Maximum concentrations recorded in other Areas of Concern include 0.144 mg/kg in Thunder Bay (Boyd, 1990) and 0.115 mg/kg at the mouth of the Don River in Toronto (Boyd, 1988).

Surficial sediments contained up to 0.007 mg/kg (dry weight) of dieldrin in Thunder Bay (Boyd, 1990), 0.026 mg/kg in Peninsula Harbour (Jardine and Simpson, 1990), 0.104 mg/kg in the St. Marys River (Hesselberg and Hamdy, 1987), 0.008 mg/kg in Collingwood Harbour (Jaagumagi and Persaud, 1992), 0.004 mg/kg in Penetang Harbour (Jaagumagi and Persaud, 1992), 0.017 mg/kg in the St. Clair River (OMOE and MDNR, 1991), 0.037 mg/kg in the Niagara River (Creese, 1987), 0.011 mg/kg in Hamilton Harbour (OMOE, OMNR, OMAF, EC, FOC and RBG, 1989), 0.016 mg/kg, 0.100 mg/kg 0.007 mg/kg and 0.008 mg/kg in Toronto's Humber Bay, Ashbridges Bay, East Headland and Bluffer's Park, respectively (Jaagumagi and Persaud, 1992), 0.005 mg/kg in Frenchman's Bay (Jaagumagi and Persaud, 1992), 0.153 mg/kg in the Bay of Quinte (Poulton, 1990) and 0.029 mg/kg and 0.027 mg/kg, respectively, near Maitland and Cornwall in the St. Lawrence River (Wilkins, 1988; OMOE and EC, 1990). These values exceed the proposed 'lowest effect level' sediment quality guideline of 0.002 mg/kg. Such exceedances therefore result in concerns over the toxicity of dieldrin to the more sensitive species of sediment-dwelling organisms and possible biomagnification up through the food chain.

Maximum concentrations of dieldrin in samples of benthic macroinvertebrates were 0.003 mg/kg wet weight in oligochaetes from the St. Marys River (Jaagumagi et al., 1991c) and 0.008 mg/kg in leeches from Canagagigue Creek (Jaagumagi et al., 1991a). Emergent (adult) caddisflies or mayflies contained up to 0.020 mg/kg (dry weight) in the St. Clair River, 0.071 mg/kg in the Detroit River, and 0.004 mg/kg to 0.022 mg/kg in inland waters. Aldrin was detected at only a few of these locations, at a maximum of 0.0003 mg/kg (Kovats and Ciborowski, 1989). Although aldrin was not detected in sculpin from the St. Marys River at a method reporting limit of 0.001 mg/kg wet weight, levels of dieldrin ranged up to 0.015 mg/kg and 0.025 mg/kg (Jaagumagi et al., 1991c) and from Toronto (Jaagumagi et al., 1991d), respectively.

Dieldrin is not routinely analyzed for in Ontario young-of-the-year fish and sport fish samples. Aldrin, which is routinely analyzed for, is only present at non-detectable or low concentrations and is not a contaminant of concern in Ontario sport fish (Cox and Ralston, 1990).

Mirex

Mirex was manufactured in Niagara Falls, New York and was primarily used as an insecticide to control fire ants in the southern United States. However, it was also used as fire retardant in plastics, electronic components, caulking and in fabrics, and was imported into southern Ontario by two companies for use in their manufactured plastic products. The use of mirex was banned in 1978 by the USEPA (Cox and Ralston, 1990; deBarros, 1984).

The main sources of mirex are located in New York State in the Niagara River and in the Oswego River, both of which are tributaries of Lake Ontario. This has led to exceedances of sediment and biota criteria and consequently, use impairments in this lake and in downstream areas in the St. Lawrence River.

Although locally elevated concentrations of up to 20 ng/l have in the past been detected in the upper Niagara River near U.S. sources (MOE, unpublished 1983 data), concentrations of this organochlorine contaminant in water do not currently exceed the PWQO for the protection of aquatic life of 1 ng/l. On the other hand, levels in some sediments and fish from the Niagara River and from Lake Ontario exceed the proposed OMOE sediment quality guideline and the GLWQA objective for the protection of higher trophic levels (Tables 2.4 and 2.5).

In the Niagara River, the suspended sediment-associated loading of 0.014 kg/d increased significantly between Fort Erie and Niagara-on-the-Lake and was due to a concentration of 0.0217 ng/l (equivalent water concentration) at the outlet of the river (Niagara River Data Interpretation Group, 1988).

Maximum surficial sediment concentrations of mirex were usually less than the 0.005 mg/kg (dry weight) minimum reporting limit in sediments from Ontario waters of the lower Niagara River, but ranged up to 0.055 mg/kg (Creese, 1987). Mean surficial sediment levels in the Niagara and Oswego anomalies of Lake Ontario were 0.024 mg/kg and 0.012 mg/kg with maxima of 0.043 mg/kg and 0.019 mg/kg, respectively in 1976 (Holdrinet et al., 1978). Mirex has also been detected at low levels in Toronto's Humber Bay with a maximum of 0.010 mg/kg (Jaagumagi and Persaud, 1992) and downstream of Cornwall in the Lake St. Francis section of the St. Lawrence River at 0.003 mg/kg (Sloterdijk, 1991). In contrast, levels of up to 0.985 mg/kg have been found near U.S. hazardous waste sites in the upper Niagara River (Creese, 1987). Of the above, those concentrations exceeding the proposed OMOE 'lowest effect level' sediment quality guideline of 0.007 mg/kg would result in concern over the toxicity of this contaminant to the more sensitive species of sediment-dwelling organisms and its possible biomagnification in the food chain (Persaud et al., 1991).
Mirex was not detected in the filamentous green alga Cladophora collected along the Ontario shore of the Niagara River in 1987, but concentrations of up to 0.263 mg/kg (dry weight) were found in samples from the New York State shoreline above the Falls. This was also the case for caged mussels exposed in the river for three weeks, with mirex only being detected at a Niagara Falls, N.Y. site, at 0.167 mg/kg (Anderson et al., 1991).

Mirex was only detected (i.e., above 5 ug/kg) in young-of-the-year spottail shiners in some years from some Niagara River, Lake Ontario and lower St. Lawrence River collection sites and therefore exceeded the GLWQA objective of substantially absent or non-detectable, for the protection of birds and animals which consume fish (Suns et al., 1991). This indicates a potential for reproductive toxicity in higher trophic levels. These locations included: Niagara-on-the-Lake in the Niagara River; and at the Welland Canal, Twelve Mile Creek, Burlington Beach, Bronte Creek, Credit River and Wolfe Island in Lake Ontario. The highest concentration in any of these recent collections was 0.008 mg/kg (wet weight) at Niagara-on-the-Lake and 0.037 mg/kg at the mouth of the Credit River (Suns et al., 1991).

While significant declines have occurred in recent years at many Lake Ontario collection sites, mirex concentrations in fish from some locations in the western end of the lake, such as the Credit River, continue to be elevated (Cox and Ralston, 1990).

In fact, mirex is still the contaminant which results in the most human consumption restrictions for Lake Ontario sport fish with a high fat content, such as salmonids, carp and catfish. For example, dorsal fillets of Lake Ontario lake trout contain a mean mirex concentration of 0.221 mg/kg, with a minimum and maximum of 0.117 mg/kg and 0.631 mg/kg, respectively. These concentrations all exceed the Health and Welfare Canada guideline for human consumption of 0.1 mg/kg (wet weight). In addition, mirex levels in larger sizes of recently-collected white sucker and walleye from the St. Lawrence River near Cornwall have also exceeded the guideline and have therefore resulted in limited consumption advisories (OMOE and EC, 1990).

Toxaphene

Toxaphene is a complex mixture of at least 117 chlorinated camphenes (deBarros, 1984). Toxaphene has been under restricted use in Ontario since 1973 (for the control of flies and ticks on beef cattle, sheep ked on sheep ticks on horses, and in a mixture with lindane for the control of mites on hogs. It has been in restricted use in the United States since 1982 (Cox and Ralston, 1990; deBarros, 1984). At present, there are no documented use impairments by this organochlorine pesticide in Ontario. However, there is presently no criterion for safe concentrations of this compound in sediments (Table 2.4).

Mean concentrations of toxaphene reported for Great Lakes whole water samples are 0.5 ng/l in Lake Superior, 1.6 ng/l in Lake Huron, 0.7 ng/l in Lake Erie and 0.6 ng/l in Lake Ontario (Strachan and Eisenreich, 1988). Monitoring data for selected Ontario tributaries indicate that toxaphene is not present in water samples at the routine analytical method reporting limit of 500 ng/l (OMOE, unpublished data). However, this is above the GLWQA specific objective and the PWQO guideline of 8 ng/l for the protection of aquatic life. Toxaphene has not been detected (at a method reporting limit of 0.200 mg/kg dry weight) in sediment samples from Toronto (Jaagumagi et al., 1991d).

Toxaphene has not been detected (at a method reporting limit of 0.01 mg/kg wet weight) in samples of benthic macroinvertebrates or of sediment bioassay organisms (mayfly larvae and fathead minnows) from such Ontario study areas as the St. Marys River (Jaagumagi et al., 1991c), Canagagigue Creek (Jaagumagi et al., 1991a), the Grand River (Jaagumagi et al., 1991b) and Toronto (Jaagumagi et al., 1991d). Toxaphene was not detected (at a method reporting limit of 0.200 mg/kg wet weight) in caged mussels exposed for three weeks in the Niagara River and in the Welland River (Anderson et al., 1991).

This pesticide has also not been detected in samples of minnows or of resident bottom-dwelling sculpins from the above areas studied by Jaagumagi et al.

There is presently no official Health and Welfare Canada guideline for the protection of human consumers of fish. However, concentrations of toxaphene in sport fish from a number of Ontario locations, when detected, have not exceeded the provisional guideline of 3.0 mg/kg used by the province (Cox and Ralston, 1990).

Appendix 'D'

Information Sources and References

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